Brass

Seven Centuries of Brass Making

A Brief History of the Ancient Art of *Brass Making* and its early *(and even recent)* method of production—*contrasted* with that of the *Electric Furnace Process*— a twentieth century achievement of

Bridgeport Brass Company
Bridgeport, Connecticut

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Historic Notes

STUDIES of the most ancient and primitive ruins indicate that the metallurgy of copper, tin and iron was practiced in its crudest form in the earliest periods of man's development. Of these three metals, copper, on account of the ease with which it is smelted, refined, and worked, was probably the first to be used. There is no definite proof of this except that as far as historic times are concerned, although iron was known, copper and bronze were in common use long before iron.

The Beginning of Metallurgy

Neither the name of the man who discovered the reduction of copper by smelting nor the method he employed will ever be known because he lived long before men began to make records of their discoveries and doings. We have, however, some evidence of pre-historic metallurgy in the many "founders' hoards" or "smelters' hoards" of the Bronze Age which have been found in Western Europe. These hoards indicate that in those days charcoal and ore were burned in a simple shallow pit in the ground and the fire continued until the copper was melted, then it was allowed to cool in the bottom of the pit forming a rough round cake of from 8 to 10 inches in diameter. Another indication of pre-historic metallurgy is the fact that copper from this period analyzed by Prof. Gowland and others shows a small percentage of sulphur, signifying that the copper was derived from smelting oxidized ores.

Prehistoric Evidences

Copper objects appear in the pre-historic remains of Egypt. In fact, they were common throughout the first three Dynasties, and bronze articles have been found that date from the fourth Dynasty (from 3800 to 4700 B. C. according to the authority adopted). In Egyptian

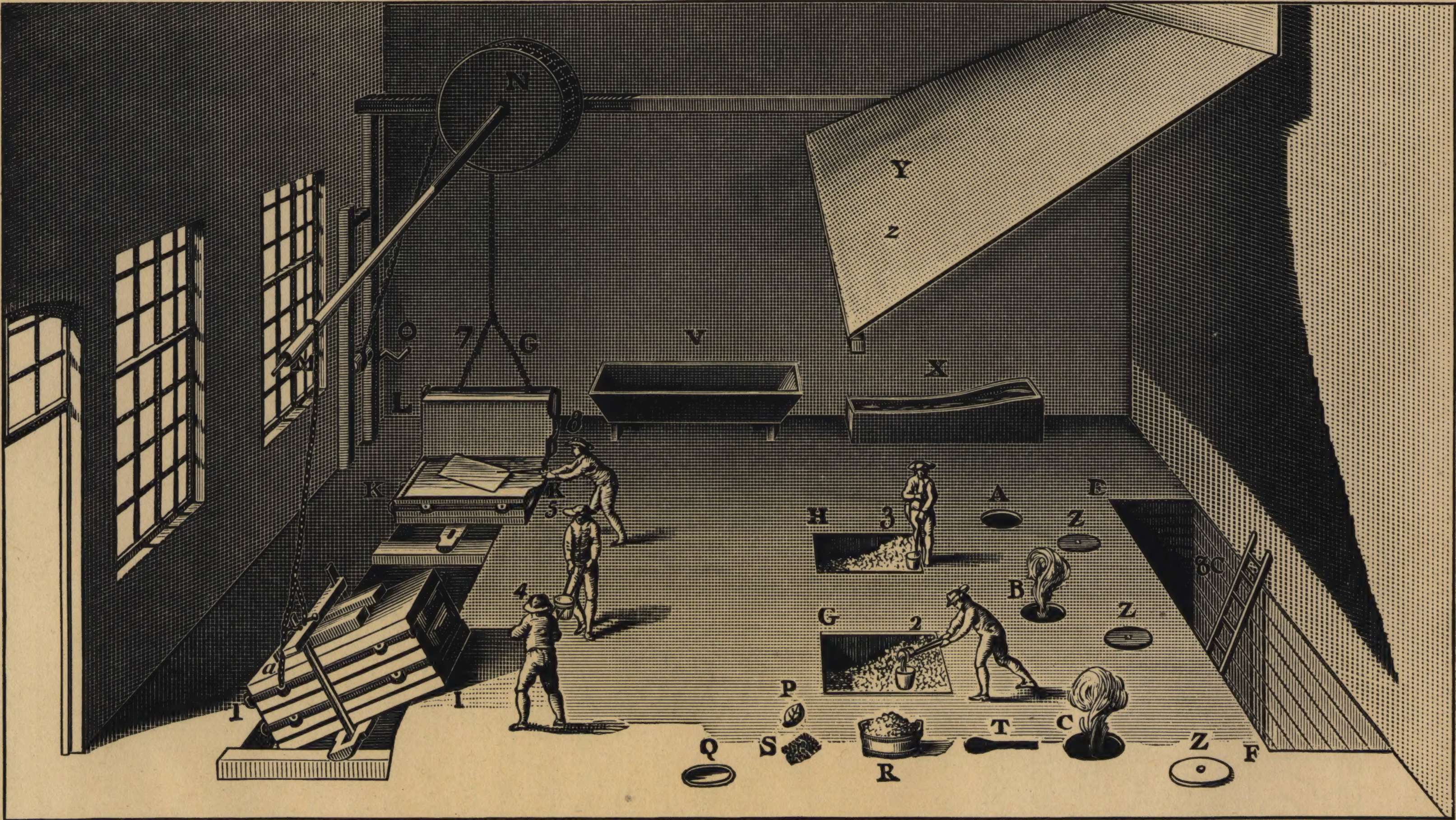


Figure 1. Interior of foundry in County of Namur on the Meuse. Illustration from paper by Galon before the Academie Royale des Sciences, 1764.

A, B and *C*. Openings to the furnaces in which the crucibles are heated.
E and *F*. Space from which the fires are tended.
G and *H*. Receptacles in which the crucibles are skimmed. These skimmings are afterwards worked over to re-claimed valuable metal.
I, K and *L*. Molds made of stone held together by iron frames.
N and *O*. Parts of the hoisting equipment for handling the molds.
R. Tub used for measuring calamine.
S. Represents small pieces of copper about one inch cube.
T. Paddle used for mixing and handling the calamine.
V. Tub in which calamine and pulverized charcoal are mixed.
X. Bed of which there are three in each foundry as the founders stay on the job 24 hours for five days in the week.
Y. Apron for catching gases from the skimming pits and the furnaces and leading them to the chimney flue.
Z. Covers to the melting furnaces.

hieroglyphics the crucible is the emblem of copper, which would indicate that crucibles were used for refining. The earliest source of Egyptian copper was probably the Sinai Peninsula, where crucibles have been found in ruins. There, too, are found reliefs dating as far back as the time of Senefern (about 3700 B. C.) indicating that he worked the copper mines.

Our knowledge of Egyptian copper metallurgy is limited to deductions from metal objects found, and to a few pictures of crude furnaces and bellows, which, however, indicate a considerable advance over the crude hearth method.

The remains of the Mycenaean, Phoenician, Babylonian, and Asyrian civilizations stretching over a period from 1500 to 500 B. C. have yielded endless copper and bronze objects, the former of considerable purity and the latter of fairly constant proportion of from 10 to 14 percent tin.

Copper

Apparently the first copper used by the ancient people came first from Sinai and then later from Cypress. Research in Cypress shows that it produced copper from 3000 B. C., and largely because of its copper it passed successively under the domination of the Egyptians, Asyrians, Phoenicians, Greeks, Persians and Romans. Our word "copper" was derived by the Romans, shortening aes cyprium (Cyperian copper) to cuprum.

Tin

As to the tin used in the bronzes, there is some difference of opinion as to its origin. Prof. Gowland, for instance, believes that the early bronzes were the result of direct smelting of stanniferous copper ores. However, there is considerable evidence to the effect that this was not true of the Egyptian and other ancient bronzes. As to the source from which the tin was obtained, Spain and Great Britain were used by the ancients. In fact, the name Britanic Isles is derived from the two Phoenician words, *breta-nac*, meaning land of tin.

Brass

The early history of brass itself is much beclouded on account of the fact that brass is often confused with bronze and other copper alloys. There are a great many references to brass in the Bible which are undoubtedly due to faulty translation, either bronze or copper being meant. For instance, Rev. John Hodgson, in a paper published by the Society of Antiquaries, Newcastle-upon-Tyne, in 1822, and entitled "An Enquiry into Aera when Brass was used in Purposes to which Iron is Now Applied", said: "In tracing the connection between ancient implements of brass discovered in Britain and the mercantile people along the shores of the Mediterranean Sea, it will be necessary to direct our attention to the information which the ancients have left us concerning their knowledge of Tin, which is by far the most common of all the alloys which they used with copper in making brass." This would indicate that even in his time there was confusion in the designation of brass as we understand it today.

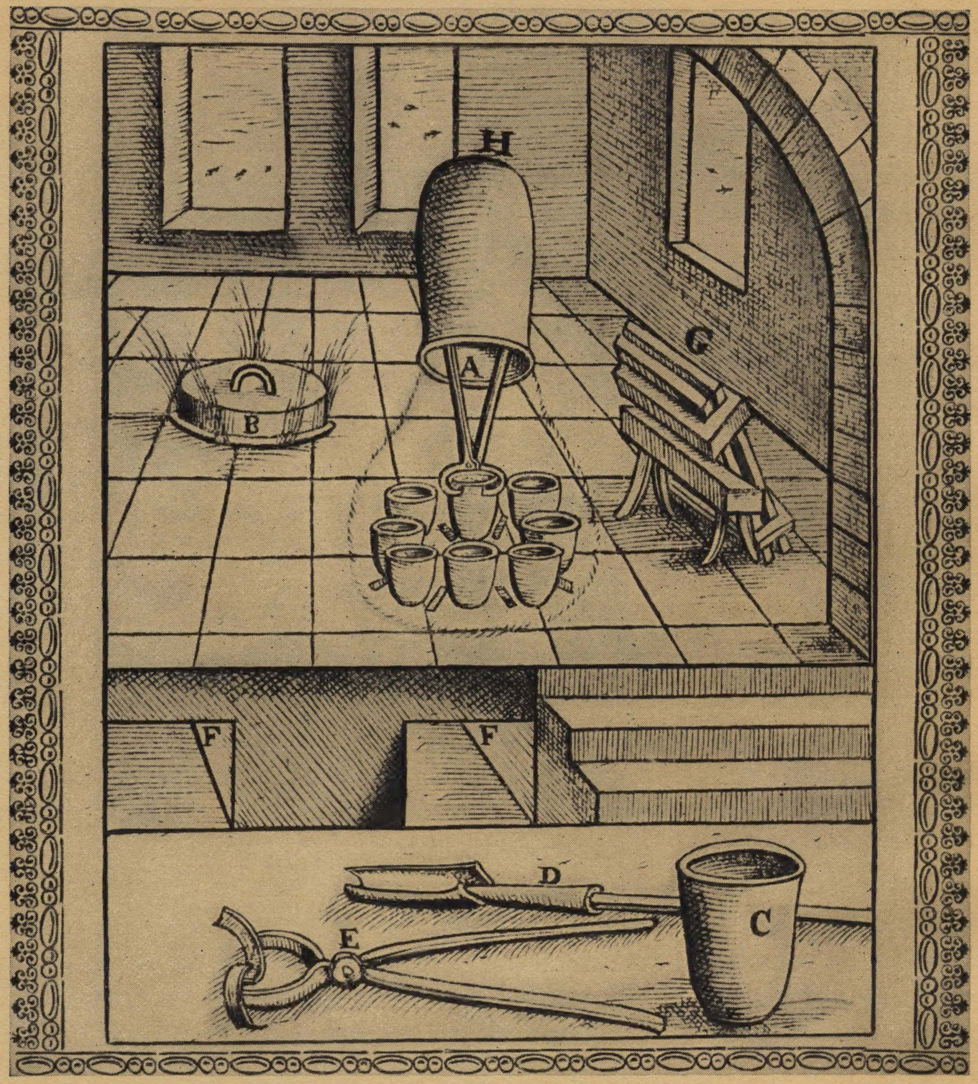


Figure 2. Brass foundry. Illustration taken from Ecker's "Untererdische Hofhaltung," page 261, published in 1672. The literal translation of the reference letters is as follows:

A. Interior view of a brass furnace showing the arrangement of the crucibles and how they are set in place.
B. Furnace in action.
C. Crucible.
D. Shovel for the calamine.
E. Pair of tongs for handling the crucibles.
F. Draft opening of the furnace.
G. Mold made of British stone.
H. Represents the master caster.

According to description given by the author, calamine and fine coal were mixed together, with water and salt. The crucibles were heated and 46 pounds of the calamine mixture were divided among eight crucibles, then 8 pounds of copper were placed in each crucible. After nine hours in the fire the mixture was well stirred, allowed to stand for an hour and then poured. The process here described is substantially the same as revealed by Theophilus four centuries previously.

The earliest accounts of brass making describe the use of calamine (a zinc ore) with copper and it is not until the eighteenth century that the practice of making brass with metallic zinc came into use.

Zinc

Zinc as a metal was known in the Far East long before the Europeans had succeeded in separating it from its ores, and it was imported from the East in considerable quantities as early as the sixteenth and seventeenth centuries. Spiauter, from which our term "spelter" was derived, is one of the names under which Easterners marketed zinc.

Brass Literature

Although brass objects dating back to pre-historic times have been found, and many references are made to brass in the earliest literature, the confusion of terms makes it impossible to be certain that brass is meant. The first unmistakable reference to brass in literature is made by Dioscorides in the first century; and the first accurate technical description of brass making does not appear until the thirteenth century, when Theophilus described the calcining of calamine and its mixture with finely divided copper in glowing crucibles. This process was described many times subsequently, and was in general use, substantially as described by him, down to the eighteenth century.

Brass Making in the Middle Ages

The earliest picture of brass making equipment that we have been able to locate is reproduced in Figure 2 from Ecker's "Untererdische Hofhaltung", page 261, published in 1672. According to the author's description, which is very meagre, calamine and fine coal were mixed together, with water and salt added. After heating the pots, 46 pounds of calamine were divided among 8 pots, and then 8 pounds of copper were put in each pot. The heat was applied for nine hours, when the mixture was well stirred, and then allowed to stand for an hour, when it was poured into the mold G, made of Britain stone, so called because it was imported from Great Britain. Though this book was printed in 1672, the process it describes is the same as revealed by Theophilus four centuries before.

A very much better illustration of a brass foundry of this type is contained in an article by Galon, printed in 1764 in Volume V of the Proceedings of the Academie Royale des Sciences. In this article Galon described the art of brass making as practiced at that time. This was followed by two other contributions in the same volume, one by Swedenborg which covered briefly the practices of the various countries of Europe, and another by M. Duhamel du Monceau who described in detail the equipment and operation of a works in Ville-Vieu. These three articles, together with beautiful illustrations, give a very complete technical description of brass founding work as carried on during the seventeenth and eighteenth centuries.

According to Galon, foundries were built in units of three furnaces each, and usually not less than two such units were involved in any

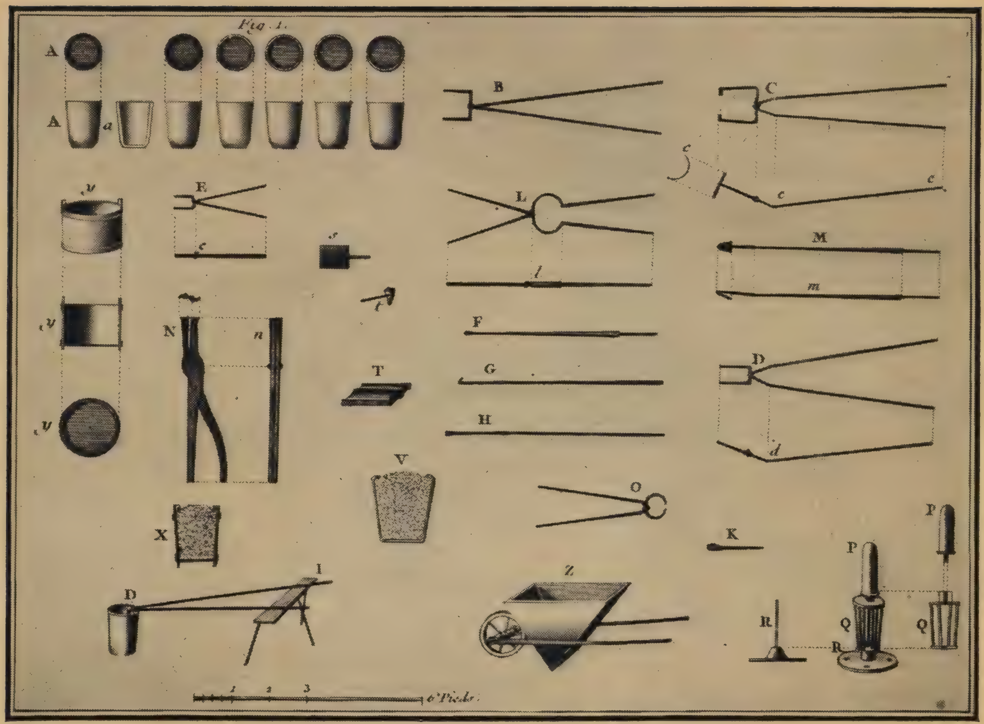


Figure 3. Tools used in the foundry. Illustration from paper by Galon before the Academie Royale des Sciences, 1764.

A. Crucibles for melting the charge.

B. Tongs used to arrange the crucibles in the furnace and to place pieces of charcoal on the edges of the crucibles.

C. Elbow tongs used to withdraw broken crucibles from the furnace and for pouring from one crucible to another. It is also used for holding the crucible while being charged.

D. Elbow tongs used to withdraw crucibles from the furnace and for pouring from one crucible to another.

E. Tongs for removing the brass bar from the mold.

F. Rod with a wooden handle for stirring the calamine in the crucible.

G. Hook for various purposes.

H. Skimming iron with a wooden handle which is used for cleaning the surface of the fused material before pouring.

I. Horse for holding the handles of the tongs D when in use for holding the crucibles while charging.

K. Iron paddle for mixing material in the crucible.

L. Double tongs for carrying a crucible or ladle when pouring.

M. Iron instrument with a wooden handle which is used to form the clay bed for the bars of the furnace.

N. Shears for cutting the brass bar.

O. Tongs for breaking the brass taken from the skimming pits.

P. Q and *R.* Potter's wheel for making clay crucibles.

T. Hammer used for breaking up copper before charging.

V. Charcoal container.

X. Calamine container.

Y. Measuring box for mixture sufficient for one slab.

Z. Wheelbarrow for charcoal and cinders.

single installation. Referring to Figure 1 the furnaces are fired from the pit, E, F, each furnace containing eight or nine crucibles arranged as shown in Figure 4. Pulverized charcoal and calamine are mixed in the tub, V, and inserted in the crucibles from the small tub, R, by means of the paddle, T, which was used for mixing and handling the calamine. Copper was used in the form of small cubes or in small balls or shot as in this way a more intimate mixture could be made with the calamine.

Having melted the charge, the crucible is removed from the furnace and skimmed in one of the pits, G and H. The man at 3 is skimming one of the crucibles while the man at 2 is pouring the contents of the crucible into a larger crucible which was used as a ladle. After the contents of the various melting crucibles had been skimmed and poured into the ladle, two men with special tongs, such as shown in Figure 3, carried the ladle as shown at 4 and 5 in Figure 1 and poured its contents into the mold while the latter was in the position shown at I. As soon as the pouring was completed, the mold was hoisted to a horizontal position, the fastenings undone, and the upper part hoisted as shown at K. The workman, 8, is seen removing the slab of brass from the mold.

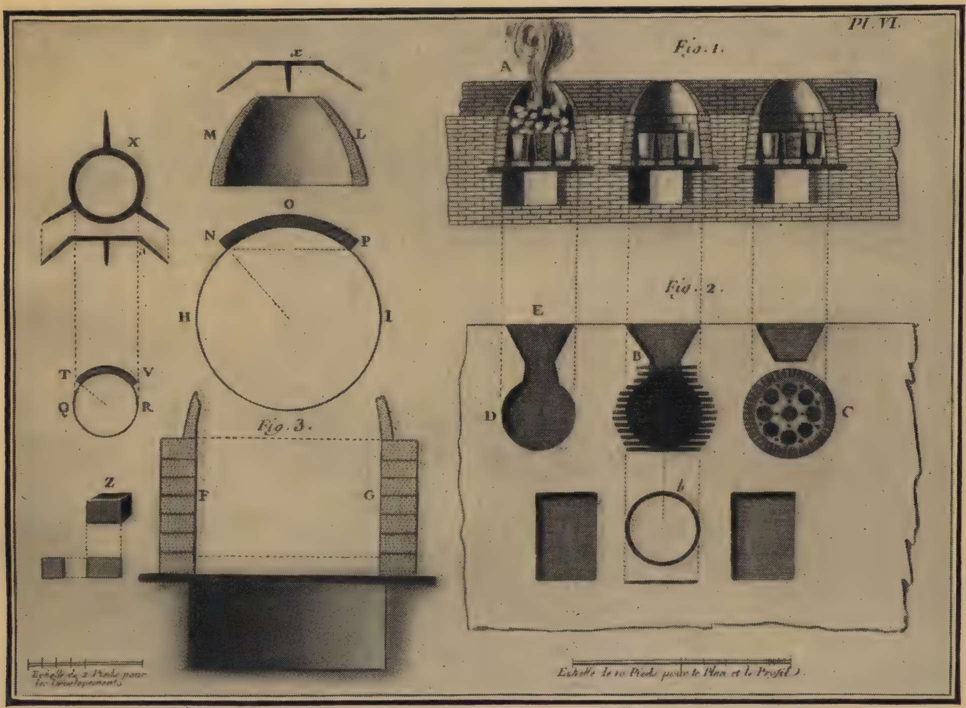


Figure 4. Brass melting furnace construction. Illustration from paper by Galon before the Academie Royale des Sciences, 1764.

The principal difference between these furnaces and the modern pit furnace is the method of taking care of the gases of combustion. Here they were allowed to pass on through the top of the furnace into the casting shop, where they were caught under a large apron which led them into a common flue; while in the modern furnace the gases are led through the side of the furnace directly into the flue. The stirring of crucibles in furnaces such as these must have been an extremely disagreeable task.

Pit Furnaces

Those familiar with present practice in brass making will be struck by the remarkable resemblance of methods employed by these early brass makers to the ones in use today. Our modern pit furnaces are constructed for more efficient combustion, but in principle they are similar to the ones shown in Figure 4. Attention is also called to the similarity between the various tongs used today and those shown in Figure 3. In order to compare these old practices with present day practice, photographs have been made showing the stirring, skimming, and pouring of brass melted in a modern pit furnace, see Figures 14, 15 and 16. Although no smoke or fumes such as seen in these pictures are shown in the old illustrations, the fact that they were there is attested to by the following quotation from Galon: "The doors and windows of the foundry are kept tightly closed while pouring. The workmen hold the end of their neckties between their teeth when they skim or when they carry or pour metal. By this precaution they diminish the effects of the fire and facilitate respiration."

Labor Conditions in the Middle Ages

Incidentally, the labor conditions existing at this time are extremely interesting. Referring to Figure 1 it is stated that there were three couches similar to the one in X in each foundry for the use of the workmen, as they spent the whole twenty-four hours of five days each week in the foundry, having Saturday and Sunday off. Quoting from Galon, "the ordinary hours of work are:

"Pouring the slabs between 2 and 3 o'clock in the afternoon. The crucibles are put into condition and the fires started at 5 o'clock in the afternoon. At 10 o'clock in the evening the fires are replenished and the second pouring is made at 2 or 3 o'clock in the morning. In other words, a complete operation requires 12 hours."

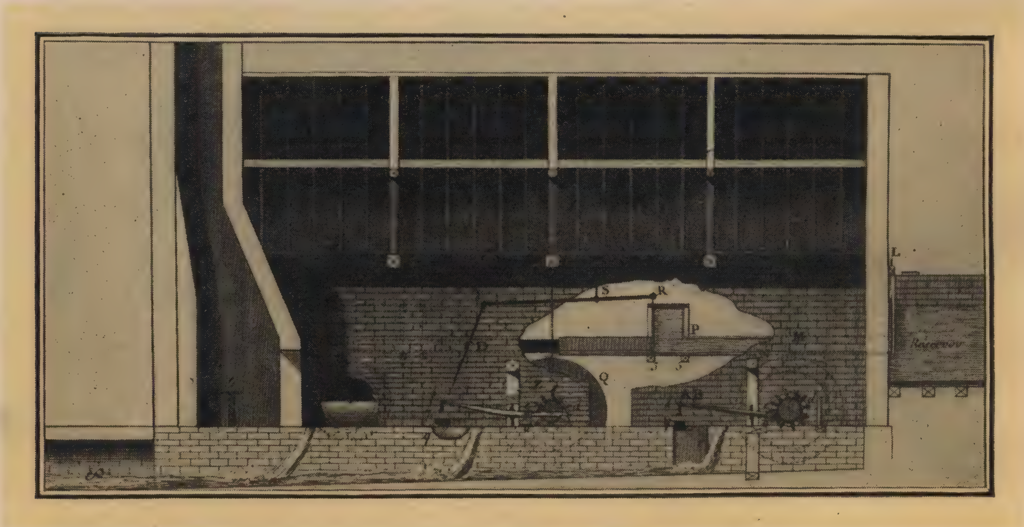


Figure 5. The ancients worked brass mostly under the hammer. The above illustration shows a forging plant operated by water power. The details of the equipment are shown in Figure 6. The practice here shown according to Galon was instituted about 1695.

According to Galon there were three workmen in each foundry—a master founder and two assistants—and the work was so laid out that when operations were to be performed which required more than three men, help could be obtained from one of the other foundry units. As far as the pay was concerned the assistants received about 12 cents for a day of 24 hours' work. They were also supplied with beer which was considered to be a necessity for all foundry men, and coal for heating their dwellings was furnished to them.

Skill of Master Founders

Evidently master founders were paid on the production basis because Galon says: "It is estimated in 1748 and during the war that the master founders earned, after expenses were covered, 4 florins for each slab of 85 pounds." With regard to the skill necessary, Galon says: "Work in a foundry demands continual care in order to feed the fires and maintain

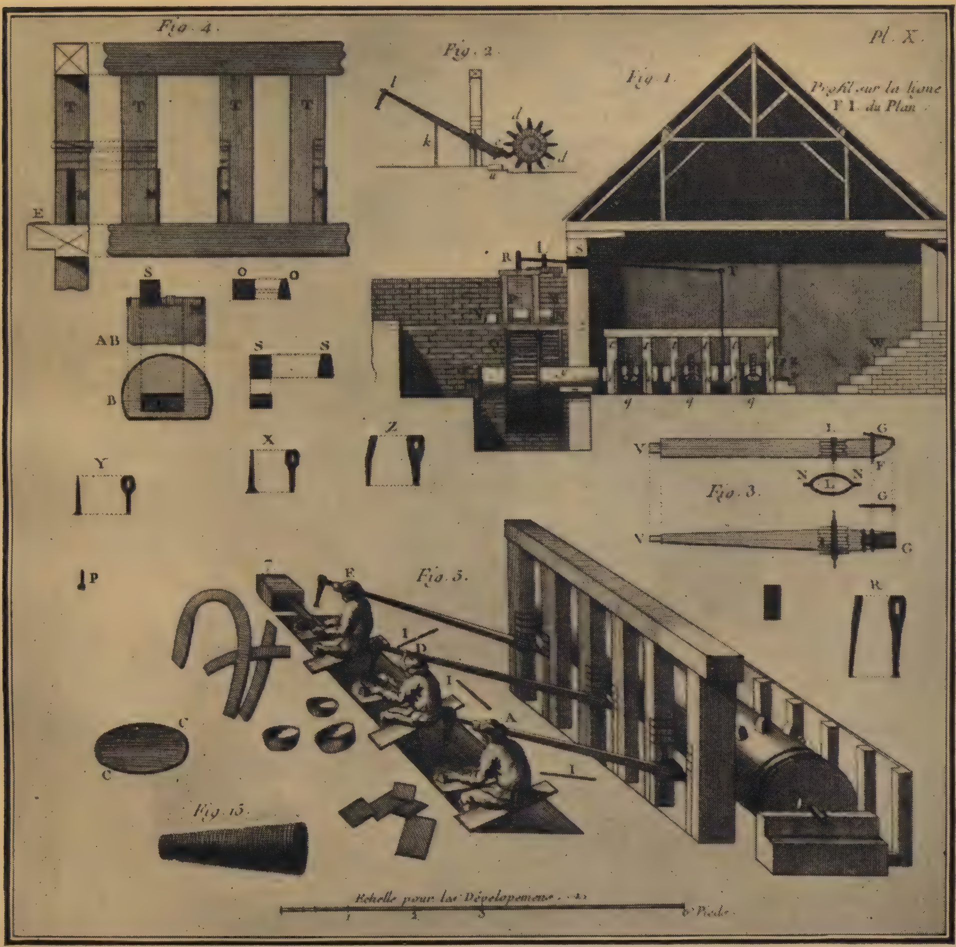


Figure 6. Details of a brass forging plant as shown in Figure 5. Each water wheel operates a gang of three hammers. The cast bars and other shapes are worked into final form under the hammer. The descriptions which accompany these illustrations in the original manuscripts, tell how the metal is heated and annealed between the successive reductions under the hammer.

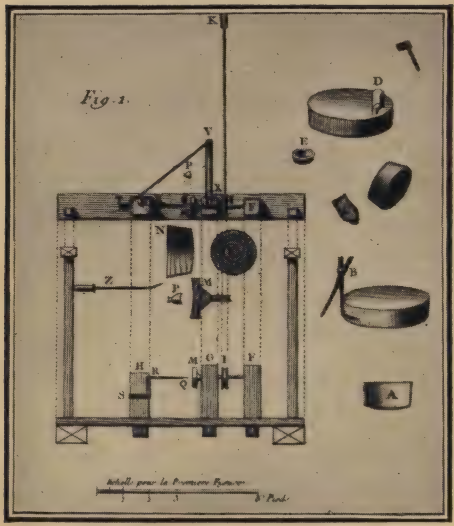


Figure 7. This illustration made in 1764, shows two views of a machine for finishing brass kettles and other vessels. The process is interesting, in that it resembles the modern process of spinning brass. The work-head is driven by belt K through the pulley I; the vessel is mounted in the work-head M by clamping between M and a movable center P which is engaged by the fixed center Q. Z is the tool used by the workman in forming the interior of the vessel.

Figure 8. After the brass is hammered into long wide strips, it is cut into narrow strips preliminary to subjecting it to a drawing operation. The shears are operated by pressure from the knee of the workman, and the width of the strip is determined by a limit guide D carried on one of the blades of the shear, as shown in the sketch at the right. The illustration is taken from Galon, 1764.

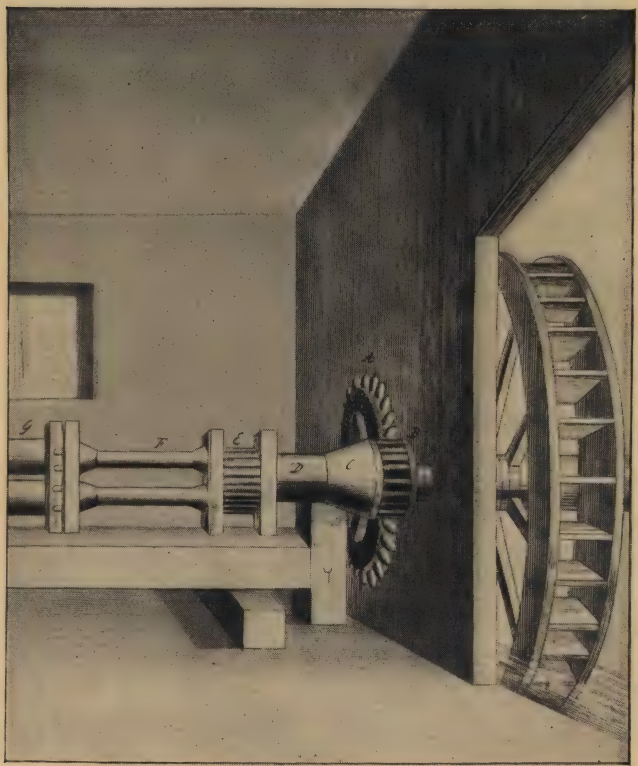


Figure 9. Although practically all copper and brass was worked under the hammer, we find in Swedenborg's "Regnum Subterraneum Sive Minerale de Cupro et Orichalco" 1734, a description of a set of rolls for rolling copper and brass sheet. An illustration taken from this book is shown here.

the necessary degree of heat for casting." He also mentions the various duties in connection with the care of the molds and disposition of the product, all of which fell upon the master founder.

Duhamel du Monceau previously mentioned refers to the skill required as follows: "The founders learn by long practice to care for the fires of the furnaces and to know when the material is in proper fusion and ready for casting." * * * "The skillfulness of founders consists in knowing the mixture and above all knowing the degree of heat which it is necessary to give. In order to be more certain they take with a small ladle a portion of molten metal and throw it on a stone and when this thin layer is cold then hammer it. If it breaks they continue the fusion or add a little Flanders scrap. If they use too much heat, the metallic part of the calamine which is zinc will be dissipated and there will remain only brittle metal which will break before it will stretch."

In attempting to explain how to judge when the metal is ready to pour, Duhamel du Monceau says: "The color of the flame indicates if the material is in fusion. At first it is red as in ordinary forges. It becomes blue when the scrap is in fusion, then after a short time it becomes clear in which state it is ready to pour. One also determines the state of fusion by plunging into the metal a stirring rod. When the metal runs to the end of the iron, the material is in condition to be poured."

From the illustrations and the meagre descriptions of technique that are available it is evident that the practice of making brass several hundred years ago was little different from that of the present day, except as regards the constituents of the mixture. If we omit that part of the practice which refers to the preparation of calamine and substitute spelter, there has been very little improvement except in minor details.

Early Brass Making in the United States

Apparently the first attempt to cast brass in the North American colonies was made in 1644 by John Winthrop, Jr., in his iron foundry at Lynn, Mass. It is also known that brass cannon were cast in Philadelphia before the Revolution. Beginning in 1725 and for 50 years thereafter, Casper Wistar, his associates and successors, in Philadelphia, hammered out stills and kettles from brass and copper and cast some brass.*

In 1802, the Grilleys, (Henry, Silas and Samuel), who had established a brass button business at Waterbury, Conn., in 1790, were joined by Abel and Levi Porter from Southington and began making buttons from sheet brass. This was the first known instance in America of brass making by direct fusion of copper and zinc according to the process invented by Adams Emerson in England in 1781. This undertaking also involved the first rolling of brass in this country.

The American brass industry was imported from England in labor, processes, and machinery. Up to 1820 the American brass makers

*Bishop's History of American Manufacturers.

struggled along engaged principally in making buttons which were sold by travelling peddlers. Competition with the English product was impossible until James Croft, an English brass maker, came to Waterbury, and hired out to the Scovill Manufacturing Company, where he introduced English machinery and processes.*

In 1830 Waterbury rolled brass became a factor on the American market and from then on the industry grew rapidly. Next came brazed tubing which was used for gas in New York City in 1836. Seamless tubing was the last important process to come from England where it was invented in 1838. This process was imported by a group of Boston men in 1848 who organized the American Tube Works in 1850.

The first really basic improvement in brass working contributed by America was the invention of the spinning process in 1851 by Hayden. From this time on American brass makers forged ahead rapidly and soon took the lead over their English competitors.

The Naugatuck Valley

The brass industry perhaps more than any other requires extraordinary skill that can only be obtained by long experience. Therefore, whenever a brass works started it was necessary to obtain one or more men skilled in the art, by taking them away from some works already in existence.

The brass industry in America started in Waterbury, Conn., in the Naugatuck Valley. The reason for this is probably due to the fact that the people of Waterbury were largely engaged in the making of pewter buttons which was an important home industry and when brass buttons came into vogue these people were threatened with disaster. They were forced to take up the making of brass buttons in order to save themselves. Fortunately the natural conditions at Waterbury, such as water power for driving the machinery, water supply for washing the metal, and wood for annealing purposes, were favorable to brass manufacture, and therefore having started there, it continued to grow.

The fact remains that the industry did begin in the Naugatuck Valley and that this valley became famous as the home of the American brass makers. These men evidently liked the place where they were born as no one has ever succeeded in inducing any considerable number of them to go to another part of the country and this is undoubtedly the real reason why Connecticut has so long remained the greatest producer of brass in the United States.

*Lathrop's "The Brass Industry in Connecticut".

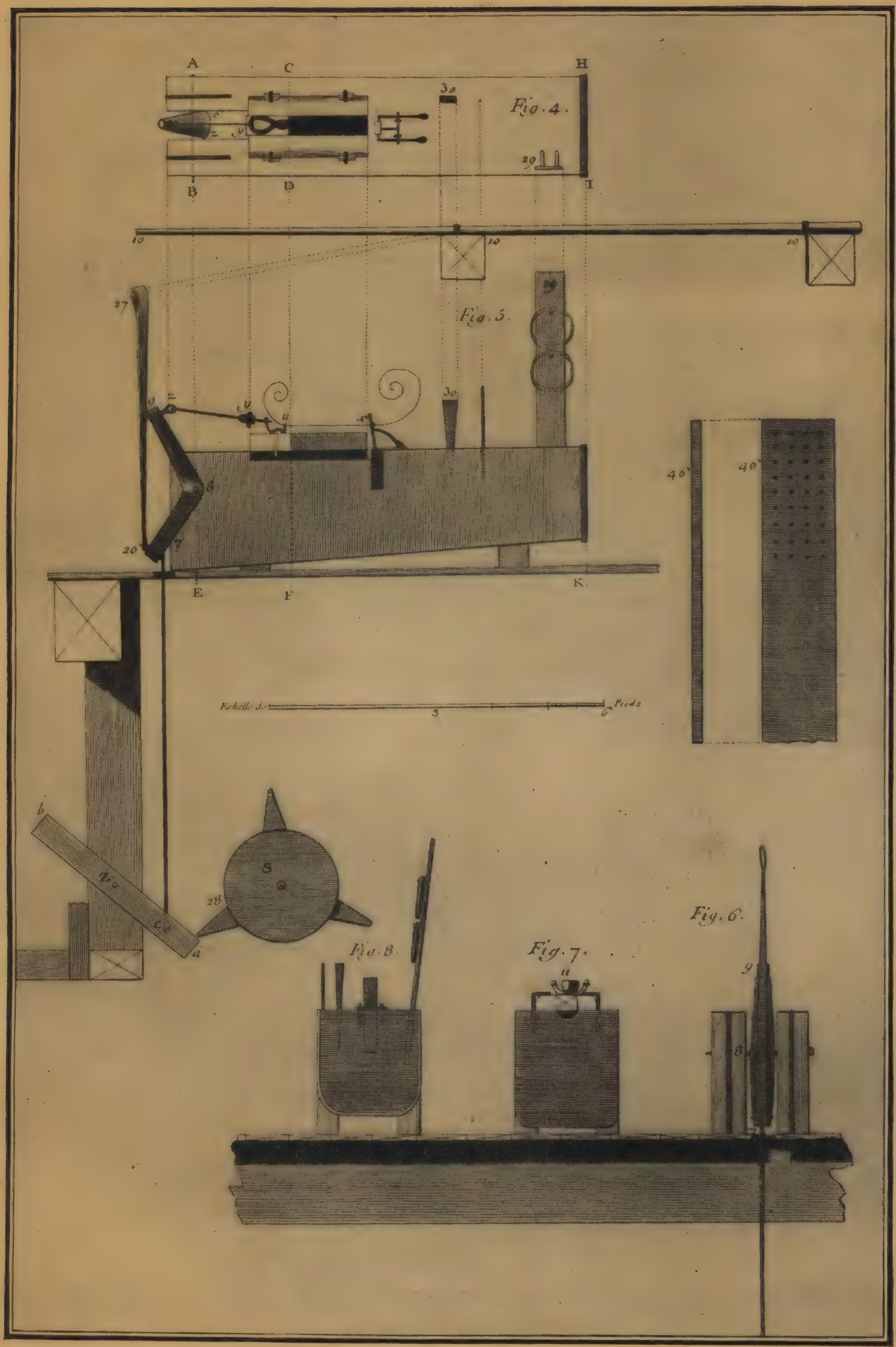


Figure 10. The strips of sheet brass referred to in Figure 8 were drawn into wire in draw-benches similar to the one shown in the above illustration. The pulling power was derived from a rotating shaft, S, the return stroke being accomplished by the retraction of a spring pole 10. 46 shows a die plate with the different size holes located in the one plate. The clamping mechanism, u, is shown in detail in Figure 11.

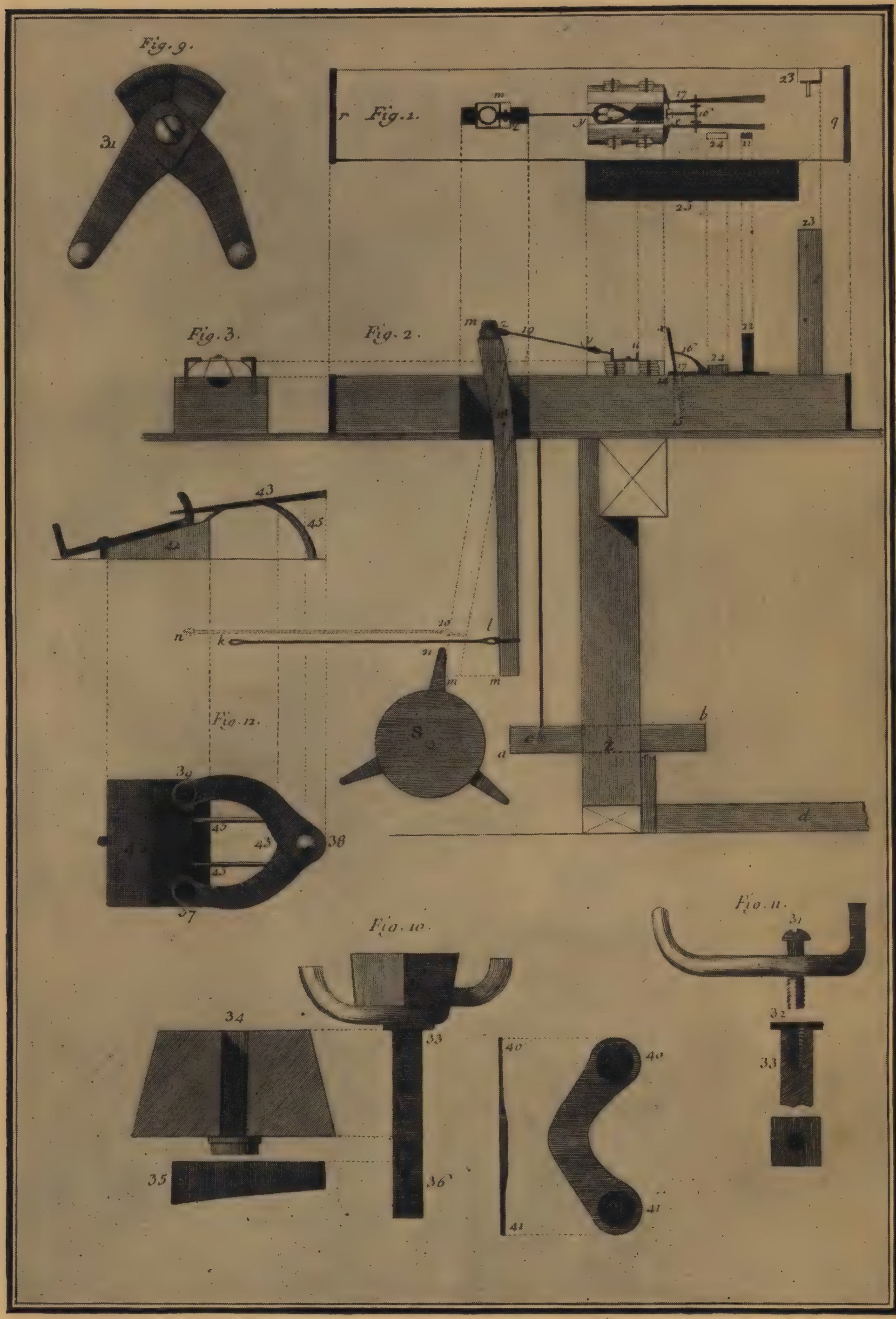


Figure 11. This illustration which is part of an article by Galon printed in 1764, shows another form of drawbench and is specially interesting on account of the details. The gripping tongs 31 are specially interesting when compared with Figure 12, which is a photograph of an installation in use in a modern plant.

Figure 12. The above illustration is interesting, on account of the fact that the drawing mechanism is practically the same as illustrated by Galon in 1764. The lever which comes up through the floor and carries the tong-grip, travels back and forth along the bench giving a short-stroke draw. In a modern plant it is used to draw the first few feet of wire through the die, so as to get enough wire to permit fastening it to the drum, then the tongs are laid aside and the drum does the drawing. Comparison between this illustration and Figures 10 and 11, shows remarkable similarity between the method here used to start the drawing operation and the method used by the ancients for all wire drawing.

BRASS MAKING

THE melting and casting of the metal in a brass mill is the most important step in the whole process of making brass materials, because any failure here cannot be rectified by later manipulation. However, in spite of the vital character of this stage of the process it is the one in which the least advancement has been made.

Melting Brass for Rolling Mills

Practically all mills that produce brass for rolling into sheets or rods, or drawing into wire or tubes, employ the crucible in the coal-fired pit furnace, which is, basically, the same method as used in the middle ages.

Referring to Figure 2, which is reproduced from a drawing made in 1672, it is seen that the three main elements of the ancient casting shop (furnace, crucible, and mold) bear a truly remarkable resemblance to the corresponding elements in the casting shop of some of the largest brass mills of today.

During the same period wonderful advances have been made by brass makers in the mechanical working of brass, so that it cannot be said that the practice of casting has remained stationary because brass makers have not tried to improve it. They have tried, and up to very recently it seemed as though it simply could not be done. The process was in the hands of skilled workmen, and each master caster guarded his secrets well.

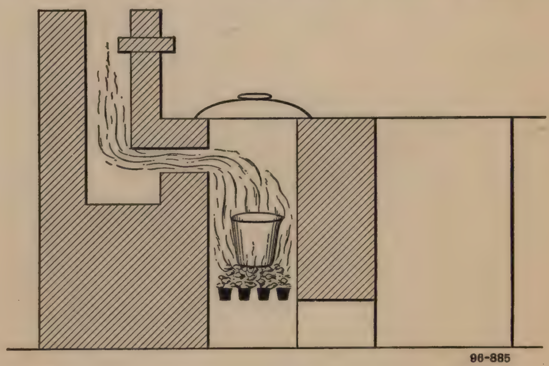


Figure 13. Cross section of a typical pit furnace.

In order to prove the statements just made with regard to the similarity of the ancient methods of brass casting and the modern ones, the operation of a modern pit furnace plant will now be briefly described.

The casting plant of the modern brass sheet, rod, wire and tube mill consists of the following main elements:

1—Furnaces 2—Crucibles 3—Molds

Furnaces

The furnaces are almost without exception of the square, natural-draft pit type and usually employ anthracite coal for fuel. Figure 13 shows a typical cross-section of such a furnace.

It should be noted that the principal difference between this furnace and the furnaces used in the middle ages is that the gases of combustion

are carried off at the side, and lead to a chimney while in the ancient furnaces they were allowed to pass up through the top and into the casting room. Then, too, the old furnaces were made large enough to hold a number of crucibles, usually eight (see Figure 4), while nowadays there is one furnace for each crucible. The modern practice is to use anthracite coal in most instances although coke is also used quite extensively. In ancient times charcoal or wood was the fuel.

Crucibles

The crucibles which are ordinarily made of clay, and graphite, usually have a capacity of from 160 to 300 pounds of metal. They require great care in handling in order to obtain a satisfactory life, and for this reason and others they constitute one of the weakest elements in the casting shop. Ordinarily the life of a crucible is from 25 to 35 heats, depending upon the manner in which it is handled, and some casters by virtue of special practices get even longer life out of their crucibles. Comparing modern crucibles with those used in the middle ages, it is difficult to see any appreciable difference except the introduction of graphite, which has greatly increased their durability.

Figure 14. A line of pit furnaces in a modern casting shop. The men here shown are stirring the metal, anthracite coal used for laying the fires is stored in bunkers located directly over the furnace openings. Empty crucibles and half crucibles may be seen at various points along the tops of the furnaces. In the upper right hand side is seen a portion of the hoist used for raising the crucibles and manipulating them during the process of skimming and pouring.

Molds The modern mold is made of soft, gray iron, hand finished. Metal intended for sheet brass is cast in flat bars of varying widths, while metal for rods and wire is cast in cylindrical billets. Metal for tubes is cast either in solid or hollow cylindrical billets, depending upon the process employed. In ancient times stone was used for molds.

Operation Casting in this type of plant is entirely up to the caster. He, with his one or more assistants, controls the fires, charges the crucibles, stirs and skims the metal, prepares and pours the molds. The whole process from start to finish is up to him, and he is usually paid on the basis of the output of good metal he attains.

The eight to twelve fires under the charge of one boss are all started at one time. The crucibles are warmed carefully before charging with scrap and copper ingot. If the crucibles are not carefully dried out and gradually brought up to heat, they will flake off and crack and their life will be materially shortened.

Figure 15. Skimming a crucible. The tongs with which the crucible has been lifted from the furnace are used by the caster to manipulate it during the entire operation of skimming and pouring. To keep the rope from too close contact with the heat and gases from the crucible, a link rod connects the block to the tongs. These tongs should be compared with those shown in Figure 2, as there is practically no difference in the construction. The white smoke arising from the crucible is mostly zinc oxide, which at the present moment is practically enveloping the head of the caster. This is one of the working conditions which makes the crucible process difficult.

Charging

The charging of the crucible must also be made with care. For instance, if the crucible doesn't set firmly or evenly on the bottom, it will be subjected to undue strain and is even liable to tip over. Then, too, the charge itself must be so placed in the crucible that it will not become wedged and cause excessive strain against the sides when it expands before melting. All these points and many more require the constant and keen attention of the caster and his assistants.

As the copper begins to melt, a handful of salt is added and stirred in to remove the copper oxide, and then the surface of the metal is covered with a layer of charcoal to protect it from the action of the furnace gases or the air.

After the charge is completely melted and the temperature raised to the proper point, the zinc, or spelter is added. This temperature may be gaged by the expert caster by the color of the flame.

Adding Spelter

The spelter, being lighter than the copper, will float to the top and finally oxidize and waste away unless it is thoroughly stirred in and the surface protected with a layer of charcoal or some suitable flux. In Figure 14 is a view of a modern casting shop showing a line of pit furnaces. The casters are stirring in the spelter. In the upper right-hand side of the photograph may be seen the hoisting apparatus that is used for lifting the crucible out of the furnace and manipulating it as will hereafter be described.

After the introduction of the spelter the crucible must remain in the fire long enough to overcome the chilling effect produced by the introduction of the spelter before pouring. If the crucible remains too long in the fire the metal will be overheated and an undue loss of zinc produced, while if it is poured too soon before the temperature has attained its proper value, the casting will not be good.

Temperature

The caster often judges the pouring temperature through the medium of his stirring rod. His sense of touch is so trained that he can perceive the vibration, due to the boiling of the zinc which signifies that it is time to pour.

Since all the fires are started at the same time, it naturally follows that all the various operations occur at approximately the same time. Consequently it requires extraordinary skill on the part of the caster to manipulate the fires in such a way that each crucible will be poured as nearly as possible at the time it is ready.

Skimming Crucible

The metal being considered ready for pouring, the coal is poked away from the crucible with an iron bar and the tongs with which the crucible is manipulated inserted and clamped. With a block and tackle fastened to a light jib crane shown in Figure 14 the helper hoists the crucible out of the furnace and swings it to a position on the cast iron floor as shown in Figure 15, where the caster with a skimming iron removes the dross. This photograph is an excellent illustration of the volatilization of the zinc which is going off in a white cloud because of the removal of the charcoal covering. Incidentally, this picture shows why casters often

suffer from "Spelter Shakes" which is a mild form of poisoning supposed to be caused by the inhalation of zinc oxide fumes.

The helper who manipulates the crane does so with the aid of a rope and a rod. The rope serves to hoist the crucible, while the rod, in addition to offsetting the side pull of the rope, enables the operator to push and pull the trolley and jib to any desired position, thus giving him complete control over the manipulation of the crucible. The caster has simply to tilt the crucible. This method of hoisting has been used for more than fifty years without appreciable change, although various unsuccessful attempts to replace it have been made. Its advantage is quick action.

Pouring Crucible

As soon as the crucible is skimmed it is hoisted and swung into position for pouring as shown in Figures 16 and 17. The pouring itself requires great skill as the perfection of the casting depends to a very large extent upon the manner of pouring. As is seen in the illustrations, the caster rests the edge of the crucible on the mouth of the mold, and

Figure 16. Pouring the first mold in the crucible process. The caster is manipulating the stream and holding back the dross with his skimmer iron, while he pours with the tongs. Attention is called to the great similarity between the molds here shown and the one shown in Figure 1. It will be seen, that the method of clamping the parts together is practically the same in both cases.

as he tips the crucible he holds back any dross or charcoal with a skimmer iron, and at the same time he often uses the skimmer iron to divide the stream into two parts, in this way greatly improving the chances for a perfect casting, especially where wide bars are concerned.

Preparing Molds

Previous to using, the molds are coated with a high-grade lard oil which serves a two-fold purpose, namely: it prevents the metal from acting upon the iron, and in burning at the mouth of the mold it envelops the stream in a reducing atmosphere which decreases the possibility of oxidation.

The molds are slightly inclined so as to make it easier for the caster to pour the metal, thus preventing it from striking against the sides of the mold. If the metal strikes continuously in one spot the casting will be porous on that side.

No attempt has been made here to cover the almost infinite number of fine points involved in the art of brass casting as practiced by the best men in the industry. In fact, the subject has never been reduced to an exact science and for the purposes of this booklet a more detailed description would be of little service.

Figure 17. Pouring the second mold from a crucible. This illustration shows plainly the rod and rope by means of which the assistant manipulates the jib crane for hoisting and maneuvering the crucible during the skimming and pouring operations.

DIFFICULTIES IN BRASS MAKING

Human Element

THE foregoing brief description of the routine operations in melting and casting brass, makes it perfectly plain that the human element enters into every step and detail of the process.

To keep ten fires right and take care of ten crucibles, putting in the spelter at the right moment, stirring and pouring at the right moment, is a full size job for the caster. There is a tendency among brass casters to use time as a guide in the execution of the various operations. However, this procedure cannot be relied upon for satisfactory results because of variations in the fuel, in the draft, in the weather, in the condition of the flue and in many other factors that may act to render any timing scheme for the various operations entirely unreliable.

In the last analysis it must be admitted that there is no positive way of determining just the right moment for carrying out the various important operations in the melting and casting of brass. It is simply a matter of experience, and even with experience as a guide if the man hasn't the will and the power he may not even do as well as he knows how. In other words, the character, disposition and moods of the men as well as their experience, enter into the making of brass by the crucible process.

Working Conditions

The second undesirable feature of the crucible process is due to the extremely disagreeable working conditions imposed upon the men. Even with the best ventilation they are subjected to noxious fumes and extreme heat, and the more conscientiously they execute their tasks, the worse the conditions they must endure. In Figure 15 is shown a caster skimming a crucible with his head entirely enveloped in fumes. If he attempted to dodge the fumes, he would not be able to skim the metal as quickly and perhaps not as well, the result of which would be an inferior casting. To stand over the fires and stir the metal is an extremely hot and disagreeable job and yet the quality of the metal is dependent upon the thoroughness with which it is stirred. These are only instances which illustrate that the caster in the execution of his work must practically disregard the conditions under which it is done.

Composition Discrepencies

The crucible itself is often the cause of discrepancies in the quality of the metal, due to the fact that a slight leak has permitted a portion of the mixture to disappear into the furnace so that when spelter is added the ingredients of the brass will not be in the proportions expected. The proportions are also modified by various conditions which affect the volatilization of the zinc, so that, in spite of the most expert attention, the composition of brass made by the crucible process will vary and does vary more than most brass makers are willing to admit.

The composition is also affected by the furnace gases to which molten brass in a crucible is always exposed to a greater or less degree. In general, the action of these combustion gases is to change the chemical

composition of the metal by oxidizing its ingredients and thus introducing impurities, as well as by removing a certain portion of the metal. The extent of the damage done by flue gases depends upon such factors as the temperature of the metal, the temperature of the gases, the composition of the gases, the velocity of the gases, the pressure of the air, and the perfection of the coating on the surface of the metal. Evidently, the combined result of these various factors is beyond human power to determine, except under test conditions such as may be obtained in a well-equipped laboratory.

To sum up the crucible process of brass melting, it is sufficient to say that it is not susceptible to scientific control and therefore cannot be admitted as a satisfactory manufacturing process for the production of a uniform, high-grade product. Its possibilities are dependent entirely upon the individuals that operate it and the product can be controlled only by thorough inspection and conscientious scrapping of all metal that is below the standard.

POSSIBILITIES OF THE ELECTRIC FURNACE

FOR a number of years brass makers have realized that the electric furnace offered many important possibilities for brass melting, but actual experiments were discouraging in that they revealed difficulties that for a number of years seemed insurmountable, or at least of sufficient importance to prevent the commercial utilization of electric furnaces for brass melting.

Before taking up the description of any particular type of electric furnace it may be well to consider the possibilities resulting from the mere substitution of electric heating for fuel heating. By looking at the problem in this way it will be evident that the electric furnace offers a solution of the brass melting problem only in the event that the proper type is chosen, and the mechanical design carried out in the light of experience in the melting of brass.

Gases

All electric furnaces eliminate the possibility of contamination of the metal from furnace gases since there is no fuel used and therefore no gases generated.

Heat Control

All electric furnaces possess the possibility of heat control, but not all possess even the possibility of temperature control when the matter of temperature distribution is considered. In brass making, temperature distribution is of first importance and a furnace that does not rapidly transfer the heat input to all parts of the metal without superheating any local portion, cannot be successfully employed.

Stirring

On account of the fact that spelter floats on copper, it is necessary that provision be made for stirring the metal, and not all types of electric

furnaces possess even the possibility of providing in a practicable way for this essential operation.

Heat Insulation

All types of electric furnaces may be so well insulated as to remove the disagreeable high-temperature conditions under which the men must work. Also any type of electric furnace may be mounted mechanically so as to facilitate the charging and pouring of the metal thus reducing to a minimum the skill and labor required.

Spelter Loss

All types of electric furnaces offer the possibility of enclosed operation, although the commercial realization of this possibility is not always possible. Spelter loss depends not only upon enclosing the space above the surface of the molten metal, but also upon the temperature, the temperature distribution, the pressure, and the length of time that the metal stands in a molten condition. Consequently the effect of the electric furnace on spelter loss depends entirely upon the type and design of the furnace. Some electric furnaces would produce a spelter loss much greater than does the crucible process.

In short, the electric furnace offers the possibility of applying scientific principles in a commercial way; that is, an electric furnace designed to utilize all the possibilities presented should practically eliminate the personal element of the operator and render the process susceptible of accurate control in accordance with carefully worked out plans.

ELECTRIC BRASS FURNACES

THE Bridgeport Brass Company for the last sixteen years has been conducting a series of investigations in its private laboratories for the purpose of reducing the process of brass making to scientific principles that could be effectively applied in the casting shop.

In the judgment of the Bridgeport Brass Company's investigators, the electric furnace offered the only possible solution of their problem. Accordingly experiments were begun with electric furnaces and these experiments indicated that even the best furnace designs on the market did not meet all the conditions which they considered necessary to the satisfactory solution of the brass melting problem.

Furnace Classification

Electric furnaces may be classified in various ways, depending upon the point of view. From a metallurgical standpoint the method of heat production may be classified as follows:

1—Heat produced exterior to the metal to be melted.

2—Heat produced on the surface of the metal to be melted.

3—Heat produced within the metal to be melted.

Separate Resistor Type

The first method includes the separate resistor-unit type in which the heat is generated in a special resistor and conducted to the metal to be melted through the walls of the hearth and by reflection from the arch or dome of the furnace. One disadvantage of this method is that special

provision must be made for stirring. Then, too, the heat transfer from the surface toward the interior does not give favorable conditions for uniform temperature distribution throughout the mass of the metal.

Indirect Arc Type

Another type of exterior heat generation is the indirect arc. The disadvantages of this type are the same as in the resistor type except that the source of heat being more concentrated, the tendency to local overheating of the metal is correspondingly greater. In one type of furnace this tendency is combatted by constructing the furnace in the form of a cylinder swung on its long axis and rolling it continually first in one direction and then in the other. In this way the metal is mixed, the heat absorbed by the walls is equalized by contact with the metal, and the surface of the metal nearest the arc is continually changed.

Another type of indirect arc furnace which is successful in overcoming the tendency to local overheating is of the same general form as the furnace described in the preceding paragraph, except that it rotates continuously in one direction and pours from an opening in the end, while the oscillating furnace pours from an opening in its cylindrical surface.

Other than these disadvantages this type of furnace when properly designed may possess all the advantages listed under the "Possibilities of the Electric Furnace." It also may be added that this method of heat generation is not the most efficient from the standpoint of energy economy and the size of the furnace is larger than necessary with either of the other two types.

Direct Arc Type

The second type, in which the heat is generated at the surface, is represented by a direct arc sprung between the surface of the metal to be melted and one or more suitable electrodes. This type of furnace on account of the excessive concentration of heat production is not considered suitable for brass melting and therefore will not be considered here.

Resistor Type

In the third type, the metal itself is utilized as a resistor and the flow of electricity through the metal may be established by induction from a primary winding, or the electricity may be introduced through electrodes. The disadvantage of this type of furnace is that a molten charge is necessary to start it. When properly constructed to utilize pinch effect, motor action, and heat circulation, this type of furnace can be built so that it will automatically circulate the metal and produce violent stirring with a resultant high degree of uniformity in temperature distribution.

Induction Type

For the high-zinc brasses the Bridgeport Brass Company adopted the third type of furnace, using as heating element the induction unit invented by J. R. Wyatt and controlled by the Ajax Metal Company.

The Wyatt heating element consists of an arrangement of circuits as shown in Figure 18. The primary is connected to the alternating current source and may be wound for any commercial voltage. The secondary

consists of a V shaped mass of metal confined to narrow passages on two sides and open on the upper side. In the narrow passages three forces operate, namely; pinch effect, motor effect, and gravity effect. The head of molten metal above the V in the chamber of the furnace prevents the pinch effect from actually rupturing the circuit, although it does cause contraction which results in motion of the column in the direction of least resistance. Contraction also results in the generation of extra heat which further accentuates the motion.

Theory of Operation

At any instant the electric current in the two converging channels is in opposite directions. Therefore, a repulsion, called motor effect, is produced between the two which tends to throw the liquid out of the passages. Observation has shown that the liquid rises along the outside surfaces of the passages and descends along the inside surfaces.

The application of heat at the bottom of the mass of metal causes circulation which draws the colder metal continually to the bottom and in this way effectively distributes the heat throughout the mass.

The combined effect of these three actions is to cause a violent propulsion of metal out of both legs of the triangle which thoroughly mixes the charge and carries the heat to all parts of the bath.

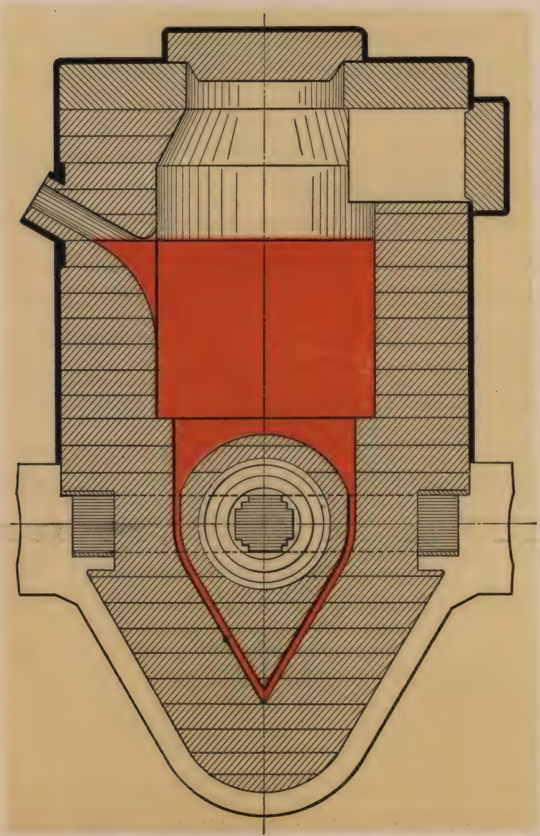


Figure 18. Elementary diagram of Wyatt heating element

For other copper alloys such as bronze and Phono-Electric, the Bridgeport Brass Company uses the indirect arc furnace of the Gillett type. This furnace is built in the form of a cylinder and is mounted in a cradle so arranged that the furnace is rotated automatically first in one direction and then in the other. The electrodes enter in the center of the two ends and coincide with the axis of rotation.

With these furnaces the Bridgeport Brass Company is able to realize all the possibilities of the electric furnace as listed in the previous chapter; and since the casting shop is operated on the 24-hour basis, and the grades of metal are thoroughly standardized, it has been possible to build furnaces that are exactly suited to the work they are to perform.

THE ELECTRIC CASTING SHOP

OVER three years ago the Bridgeport Brass Company began to use electric furnaces on a commercial scale, and after developing types of construction suitable to the particular needs of the various alloys, steadily increased the electric equipment until it finally displaced the pit furnace entirely. Accordingly the pit furnace casting shops have been completely dismantled and the chimneys torn down. At the present time construction work is under way to more than double the productive capacity of the present electric casting shop.

Advantages of Electric Brass

With these furnaces, the Bridgeport Brass Company has been able to solve the problem of applying scientific principles to the making of brass for use in its sheet, rod, wire and tube mills and manufacturing departments. The process as developed possesses the following advantages:

1—The human element as far as the actual operation of melting and pouring is concerned is practically eliminated, because all of the factors which enter into the production of brass of a uniform and definite quality are susceptible of exact determination and control.

2—The heat input is generated within the body of the metal so that the temperature distribution is uniform.

3—The design of the furnace is such that stirring and mixing is thoroughly accomplished; in fact, the most conscientious brass caster could not stir a crucible as perfectly as the metal is stirred in these electric furnaces.

4—The temperature of the metal at various stages in the process is indicated electrically, eliminating entirely any question of skill on the part of the operator in the estimation of temperature.

5—The heat input and therewith the temperature of the metal is always under perfect control and can be adjusted to give any desired heating characteristic. Best of all, the same heating characteristic can be repeated indefinitely.

6—The purity of the metal is guarded by the exclusion of the atmosphere, the furnace chamber being entirely closed except when charging or skimming. A further precaution is the use of a layer of charcoal on top of the molten metal, which maintains a reducing atmosphere in the closed space above the surface of the metal.

7—The heat insulation is so perfect that the operator can lay his bare hand on the outside of the furnace at any time, which indicates the vast improvement in working conditions in the electric casting shop as compared with the pit-fire shop.

8—By pouring only part of a charge and then re-charging, any slight errors in weighing of the ingredients are equalized by the blending of several charges in the same furnace.

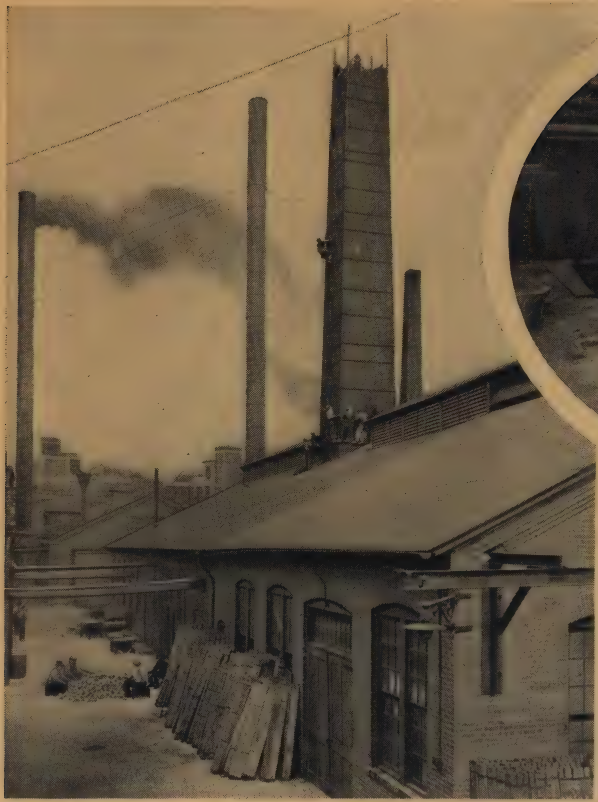


Figure 19. These views show the dismantling of the Bridgeport pit furnace casting shops and the destruction of two of the chimneys. The circular chimney was only two years old, when it was decided that the best interest of the Bridgeport product demanded its demolition to make way for electric furnace brass.

9—Mechanism is provided which gives the operator perfect control of the pouring. He can vary the rate as slowly and accurately as he may wish with the result that any ordinary operator can pour a billet as well as the most expert caster is able to do with the crucible by hand.

The combined result of these various factors is the production of a brass, uniform and homogeneous in quality and of a higher grade than is commercially possible with the crucible process. Due to the accurate control of the heating, the completeness of the protection from the atmosphere, and the entire absence of furnace gases, the composition of the metal is maintained to a remarkable degree of accuracy. In fact, practice has shown that the loss in spelter so difficult to control with the pit-fire process is less than one-half per cent.

At this point it may be interesting to describe briefly the operation of the electric casting shop in the Union Branch Plant of the Bridgeport Brass Company. At one end of the shop are situated the metal bins in which the raw materials, used in the making of brass, bronze and other copper alloys, are stored. These materials are carefully classified by

Figure 20. A line of weighing machines handling the ingredients of one of the standard Bridgeport alloys. Each man has charge of only one ingredient and has to remember only one weight. In the background are seen bins which contain raw materials classified by careful analyses. It is scientific organization of this end of the casting shop that insures an extraordinarily high degree of uniformity in the composition of Bridgeport brasses and bronzes.

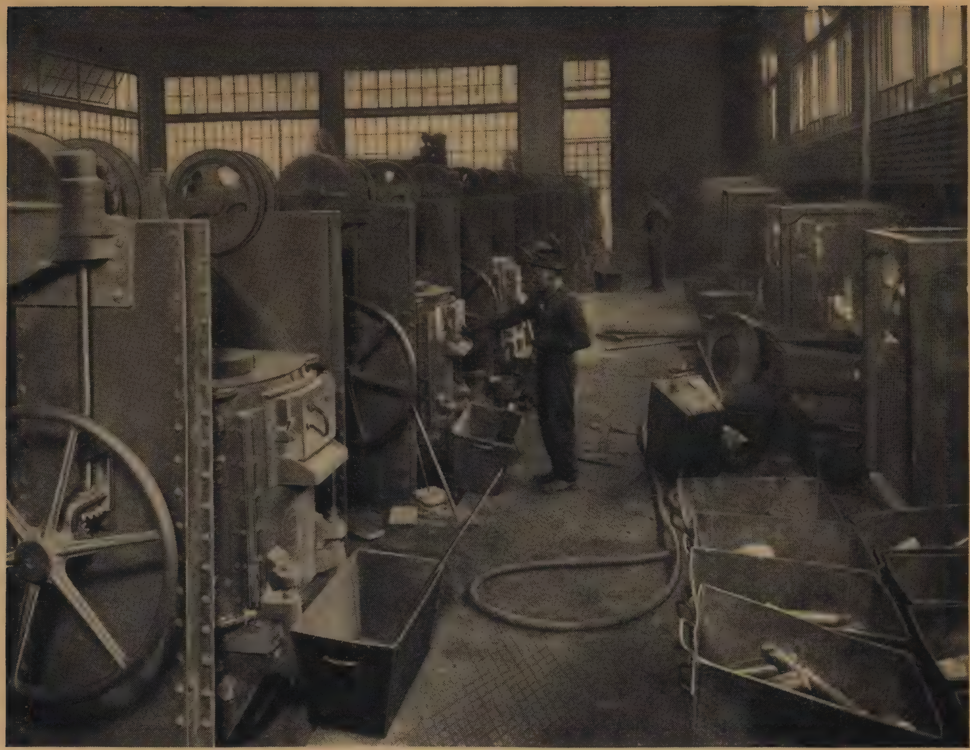


Figure 21. The charging aisle of one battery of Bridgeport electric furnaces. In the right foreground are shown, the charging cans which are made of such size that loss of any part of the charge by spilling is practically impossible. The cans are brought from the raw material stores department, by means of an overhead travelling crane. The furnaces are charged through the doors near the top.

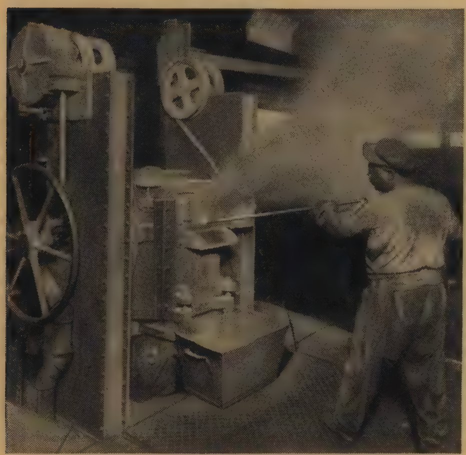


Figure 22. Skimming Bridgeport electric furnace preparatory to pouring. In order to protect the surface of the metal from the atmosphere, and to maintain a reducing atmosphere within the furnace, a layer of charcoal is kept on top of the metal which forms a smoke whenever the door is opened.

Figure 23. Pouring brass bars for the rolling mill. The caster has perfect control of the pouring through positive mechanism. With perfect ease he can vary the rate of pouring to suit the exact needs of the work in hand.

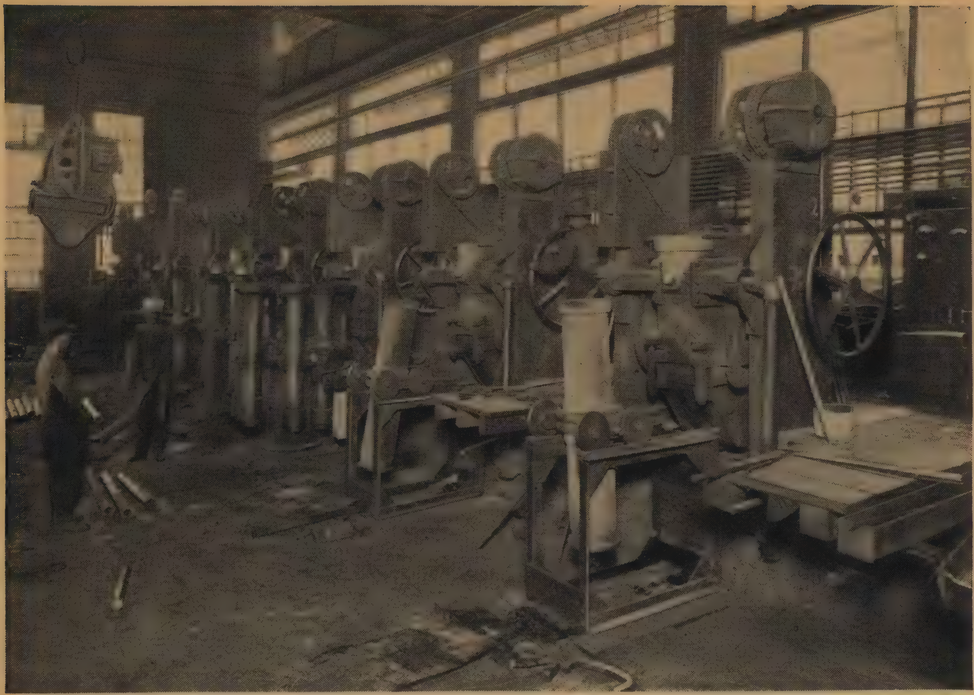


Figure 24. The pouring aisle of a battery of Bridgeport brass furnaces. These furnaces are used for pouring billets that go to the tube mills and the extrusion machine.

Figure 25. A line of induction furnaces used for pouring billets. Bridgeport Brass Company employs several kinds of electric furnaces, each furnace handling the same alloy under the same conditions day in and day out.

systematic analyses so as to assure the maintenance of a high degree of accuracy in the composition of the brasses.

Weighing Ingredients

In order to simplify the operation of weighing the ingredients and reduce to a minimum the possibility of errors, each ingredient is handled by a separate workman. In this way the process is worked out so that the weigher has only one weight and one ingredient to look after. The equipment for weighing is so designed that the material after being weighed is dumped directly into the charging can in such a manner as to eliminate the possibility of loss due to careless handling. All these precautions effectively safeguard the uniformity of the product. One line of weighing equipment is shown in Figure 20.

In order to obtain a positive check on every charge, the complete charge is weighed before it is sent to the casting shop, and if the total weight does not check exactly with the sum of the component parts, the charge is re-assembled.

Charging

The charging cans are made of such size that the charge fills them to less than half of their capacity. This procedure avoids the possibility of spilling any part of the charge before it is used. In Figure 21 is shown the charging aisle of one of the lines of furnaces. The charging cans may be seen at the right. The materials are introduced into the furnace through the charging doors plainly shown in the picture. Before pouring

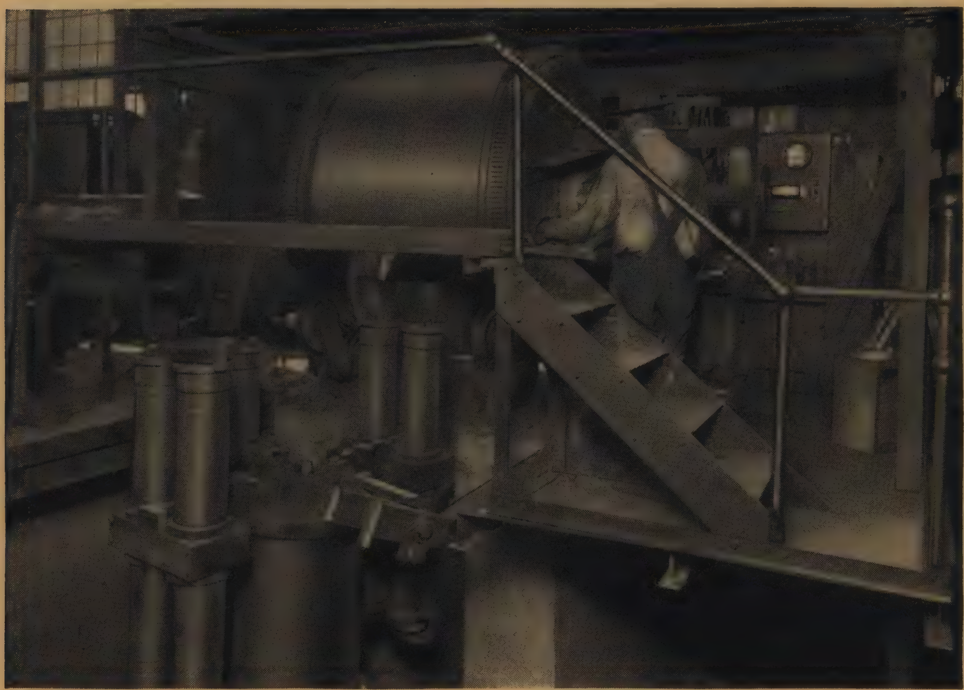


Figure 26. Pouring a billet from an oscillating indirect arc furnace. The raw material is charged from a platform above the furnace. The pouring is manipulated by means of an electric controller.

the furnace man skims the dross from the top through the charging door as shown in Figure 22.

Pouring

When the metal is ready to pour, the molds mounted on a rotating stand are put in place and the pouring accomplished by manipulation of a hand wheel. This wheel is positively geared to the tilting mechanism so that the caster has perfect control of the rate of pouring. At this point it is interesting to note that of each melt a sample is taken, and the results of the analysis of this sample are available before the billets or bars as the case may be reaches the mill to be worked into the finished product. A portion of one side of the pouring aisle is shown in Figure 24.

Scientific System

Contrasting the actual operation of the electric casting shop with that of the pit furnace casting shop as described on pages 20 to 25, it will be noted that every one of the most difficult steps of the process is accom-

Figure 27. Pouring a billet. The grease in the mold forms a black smoke which not only protects the mold from burning, but protects the stream of metal from the atmosphere, and absorbs any oxide that tends to form.

plished automatically and practically independently of the skill of the operator. The heating, the judging of the temperature, the stirring, and the pouring, all of which formerly required the skill of a master caster are now accomplished by the furnace itself.

The accompanying illustrations will give some idea of the equipment employed and indicate how it is manipulated in service. With this equipment, the Bridgeport Brass Company has been able to produce brasses and bronzes of a degree of uniformity and homogeneity previously unknown on a commercial basis.

The entire output of the electric casting shop of the Bridgeport Brass Company is made up into various products marketed by the company, such as tube, sheet, rod, wire and manufactured products. A fairly complete set of pictures has been made illustrating the most important steps in the various processes of manufacture. Beginning with the raw material furnished by the casting shop each one of these processes will be briefly described in the following chapters.

Figure 28. Taking cut off bronze billet of special turbine blading metal.

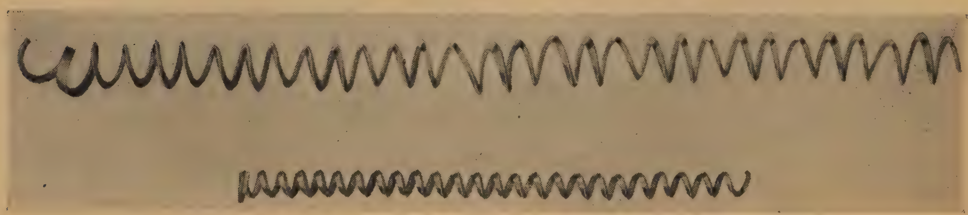


Figure 29. Chips removed from the surface of the billet shown in Figure 28. When it is considered that these chips are taken from the surface of a cast billet, it is evident that the casting itself closely approaches physical perfection.

PHONO-ELECTRIC WIRE

Properties

SOME twenty odd years ago, Phono-Electric trolley wire was developed and placed on the market by the Bridgeport Brass Company in response to a demand for a contact wire that would withstand the conditions of severe service better than hard-drawn copper. The greatest advantages of Phono-Electric wire from the railway man's point of view are: Toughness, high tensile strength, favorable arcing characteristics, and best of all, these various characteristics are permanent—the wire does not alter its properties under service conditions, which is one of the most serious disadvantages of hard-drawn copper.

Rolling

These properties of Phono-Electric wire are due first to the composition of the wire; second, to the uniformity and homogeneity of this composition; third, to the carefully controlled process of manufacture. Phono-Electric billets are delivered from the electric casting shop to the rolling mill where they are introduced into a heating furnace, the entrance to one of which is shown in Figure 30. After having reached the desired temperature, the billet is withdrawn from the furnace by sliding onto a two-wheel car as shown in Figure 31. It is then wheeled to one of the rolling mills and passed back and forth until it is sufficiently reduced in diameter, when it is coiled up and delivered to the wire mill. Figures 32 and 33 show the billet at two stages of the rolling process.

Joints

The coiled rod before going to the draw benches is joined into long lengths by soldering. The joint is prepared by sawing the ends at an acute angle, cleaning the adjacent surfaces with acid and inserting between them a sheet of silver solder. They are next bound together with wire and a brazing furnace swung into position to enclose the joint. After heating to the proper temperature the operator applies more silver to the joint and works it in thoroughly. Having completed the operation, the furnace is dropped down, the wires removed and the joint smoothed up with a file. In Figure 34 is shown the soldering equipment for two men. The joint in the foreground had just been completed, while the other one is being heated in the furnace.

Drawing

The drawing of Phono-Electric takes place in the usual way except that extraordinary care is exercised to maintain accurate dimensions. The die itself is special. It is so designed and manipulated that strains are equalized and any unbalanced wear prevented. Figure 35 shows the soldered rod undergoing the first draw. It passes from the rod reel through the die to the drum of the drawing machine and after making several turns around the drum it is wound up on a reel ready for the next operation.

Phono-Electric wire is described, and its physical and electrical properties given in separate bulletins which may be had upon request.

Figure 30. Phono-Electric billets entering the heating furnace.

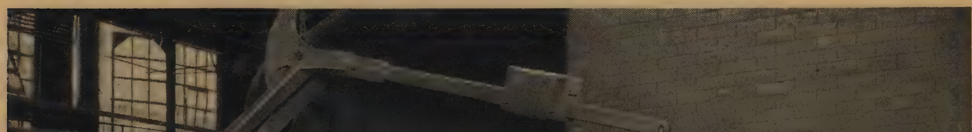


Figure 31. Removing a Phono-Electric billet from the heating furnace preparatory to inserting it in the rolls. Although the picture does not show it, the billet is nearly white hot.

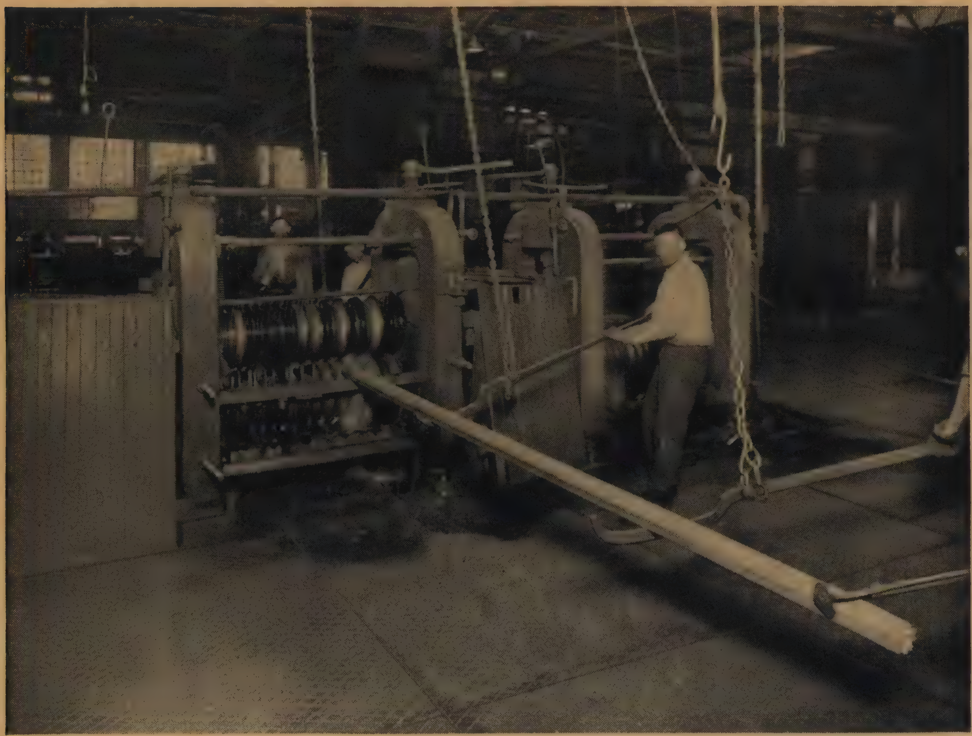


Figure 32. The same billet as shown in Figure 31 after the third pass through the rolls.

Figure 33. The same billet as shown in Figure 31 just before the last pass through the rolls, after which it is coiled up and sent to the wire mill.

Figure 34. Phono-Electric rods are soldered into long lengths with silver. A completed joint is shown in the foreground—the brazing furnace being swung out of the way. On the other side of the bench the brazing furnace is in position and the fire going. These joints have given perfect satisfaction, both as to strength and conductivity.

Figure 35. Phono-Electric rod passing through the die for the first draw. Great care is taken in every detail of the drawing of Phono-Electric wire, so as to obtain the maximum advantage from mechanical working of the wire and maintain the correct gage.

BRASS AND COPPER TUBES

THE Bridgeport Brass Company has been making seamless brass and copper tubing for over thirty years, being one of the pioneers in the making of this product. The processes employed in making seamless tubing impose extremely severe conditions on the brass maker if success is to be attained. To begin with, it is all-important that the quality of the metal be definitely known and uniformly maintained for any given result. Years of study in the research laboratories and even more years of practice in the mill have taught the Bridgeport Brass Company what conditions are necessary to the making of seamless brass and copper tubes for any given purpose, and equipment has been provided to realize these conditions on a manufacturing basis.

Seamless Tube Processes

Although there are several different methods of making seamless tubing, practically all tubing made by the Bridgeport Brass Company falls under three processes, namely; the piercing process; the cast shell process and the cupping process. The choice of these three is determined by the character of the tube to be produced. Taking up the piercing process first, cast billets slightly cupped at the end and of suitable diameter are delivered to the piercing mill from the electric casting shop.

Billets used in this process are turned so as to remove surface impurities and mechanical imperfections, and in this way insure greater perfection in the surface of the tube. Figure 28 shows the turning of a billet.

In Figure 36 we see these billets on their way into a heating furnace. In this furnace they are brought to the proper temperature and discharged at the proper moment into the intake end of the piercing machine as shown in Figure 37. The operator of the piercing mill by means of a motor controller causes the billet to be inserted into the machine by rotating the rollers upon which it rides.

Piercing

Once in the machine, it is subjected to a cross rolling action, the result of which is to cause the billet to travel through the rolls. Just as it leaves the rolls it encounters a projectile-like steel point carried on a long rod over which it is forced, rotating the meanwhile between the rolls just ahead of the point. The working parts of this very interesting machine consist of two power driven rolls, mounted at an angle to one another and having their cylindrical surfaces made up of the frustums of two cones. Just below and between these two driven rolls, is a small idler. The billet passes between the three and is drawn in by the spiral travel of the three rolls, the angles being such that the point of contact travels on the same spiral on all three rolls, giving the billet a powerful forward motion.

Fiure 36. Billets entering the heating furnace preliminary to entering the piercing machine

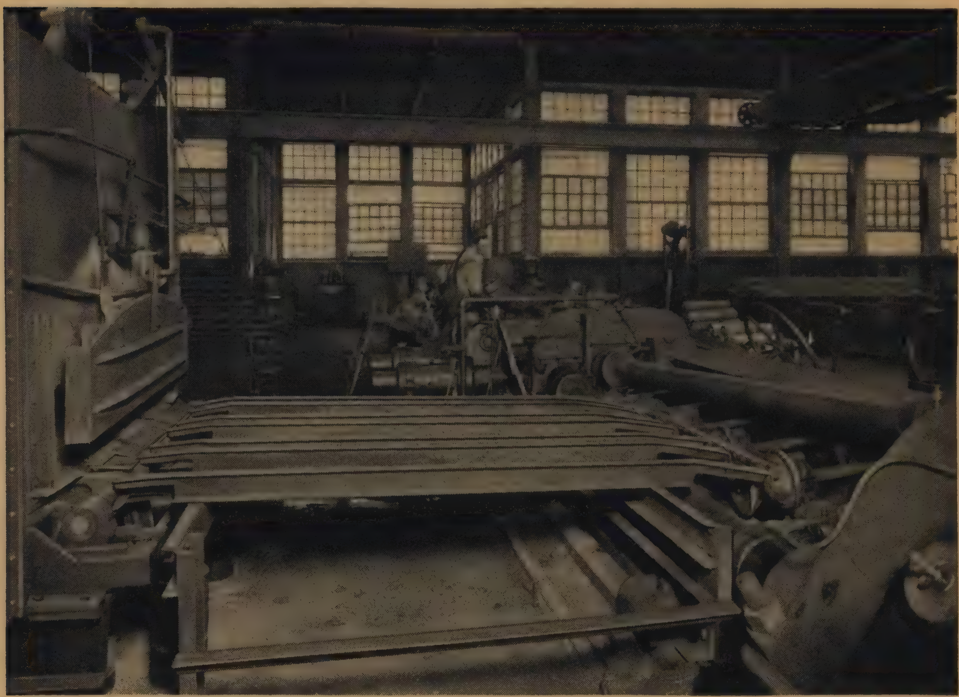


Figure 37. A hot billet has just left the heating furnace shown in Figure 36 and is about to enter the piercing machine, where it will be subjected to the cross-rolling action of three rolls placed at an angle to the axis of the billet and in such a way that the point of contact describes a spiral drawing the billet forward. Just as the billet leaves the rolls it encounters the hardened point over which it is forced to travel, the function of which is to open up the billet and form it into a tube.

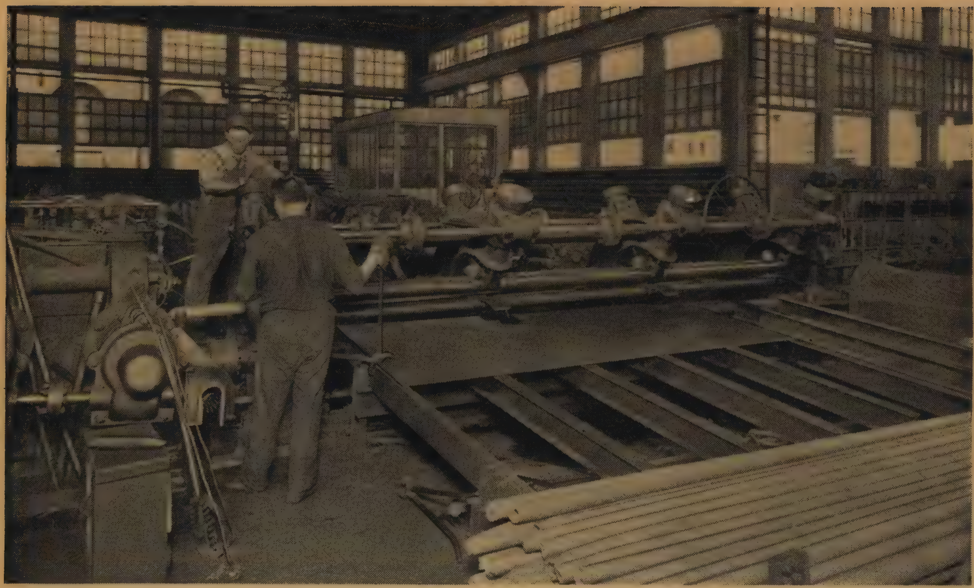


Figure 38. The pierced tube is seen emerging from the rolls and passing over the rod which carries the piercing point. One of the points which has been removed for repair is shown lying on a bench in the left foreground. Finished tubes ready to go to the tube drawbenches are shown in the right foreground.

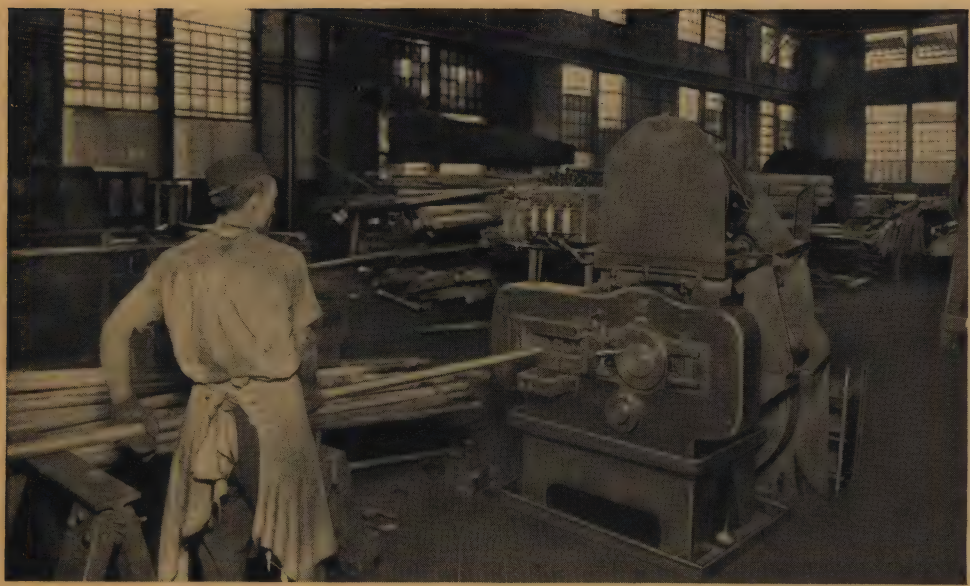


Figure 39. Pointing tubing preliminary to drawing. The openings into one of which the tube is about to be inserted are split and opened and closed continually under the action of the driving mechanism. The holes just below the pointing dies serve as gages into which the pointed tube must fit.

Figure 40. Vertical pointing machine for large size tubes. The operators are just removing a tube from the machine.

Figure 41. Drawing tubing. At the right a tube is seen partially through the die. The inside dimensions and the shape of the tube are maintained by a tapered plug held in the mouth of the die by the rod seen extending from the end of the tube. It is supported near the end of the tube by a bushing The power for drawing is supplied by a long piston working in a cylinder. As soon as a batch of tubes has been passed through the draw bench, it is picked up by a crane and deposited in the annealing department.

Figure 38 shows a tube issuing from the machine. The rod with the piercing point is inside. The points have to be changed from time to time in order to maintain the proper contour. A point that has just been removed from the machine is shown resting on a block in the left foreground.

When the billet has been forced entirely through the machine the rod is withdrawn by a travelling work-head which may be seen at the right of Figure 38, although the end of the machine is well beyond the limits of the picture. Tubes produced by this process are shown in the foreground of Figure 38.

Pointing

From the piercing mill the tubes go to the draw benches, where they are pointed and drawn. The pointing operation is shown in Figures 39 and 40. It consists simply of smashing down the end of the tube sufficiently to allow its insertion through the die and into the grip.

Figure 42 is a general view of the main tube plant. Practically all the equipment in this plant is special. One type of tube draw-bench alone contains 93 elements that are covered by patent claims. Before this mill was built, an experimental mill was set up and every detail of the process worked out experimentally and theoretically before the final decision as to design to be used in the plant was made.

Draw Benches

Figure 41 shows a group of tube draw benches. At the right is seen a tube partially through the die. The rod here shown carries the plug or triblet, which is held inside of the tube at the point where it passes through the die and maintains the internal diameter as well as preventing deformation of the circle. In the outer end of the tube is seen a bushing, which serves as a bearing and guide for the rod. The tube itself is drawn by the action of an hydraulic plunger, located on the other side of the die. These machines are so long that photographing is extremely difficult.

Annealing and Pickling

After each draw the tubes are delivered to continuous annealing furnaces which are maintained at constant temperature, the tubes travelling at a definite speed through the furnaces. In Figure 43 is seen a set of tubes on the conveyor which have just emerged from the furnace and are ready to dump into the pickle. Figure 44 shows a bunch of tubes being lifted from the pickle to be carried back to the draw benches for the next operation. This operation of annealing is of the greatest importance since it has a marked effect on the distribution of stresses in the walls of the tube and acts to prevent what is known as "season cracking."

Annealing Temperatures

The importance of proper annealing cannot be over emphasized. The Bridgeport Brass Company has studied the annealing operation with respect to temperature, rate of heating and cooling, and as a result of these studies has formulated exact specifications covering both these factors for every quality of metal turned out by the mills. In Figure 83 the results of experiments on a certain alloy are shown graphically.

Figure 42. A general view of one section of the tube mill. This tube mill is remarkable, on account of the fact that most of the equipment was developed by the Bridgeport Brass Company as a result of the operation of an experimental tube mill for a number of years.

Figure 43. A batch of tubes issuing from a continuous annealing furnace. The method by which the conveying rolls are driven is plainly shown in the machine just back of the one in the foreground. The tubes here shown are just about to be dumped into the pickle which is accomplished by the operator in the background. The temperature of the furnaces and the speed of travel through them is so chosen, that the mechanical strains from the drawing operation are equalized without detriment to the physical properties of the tube.

Figure 44. A batch of tubes being removed from the pickle to be returned to the drawbenches for the next draw.

From this diagram it is seen that the annealing temperatures affect vitally all the physical properties of the metal, and when properly understood can be used to obtain certain desired properties.

The temperature of the annealing furnaces is measured with electric pyrometers. The indicating instruments being used by the operators for making heat adjustments, and the recording instruments used for information of the engineers as well as for the operators, so that the exact history of any given batch of metal can be recorded. In Figure 61 is shown one of the recording instruments.

Straightening

When the tubes have been drawn to the proper diameter and gage, they are straightened by passing them through a set of rollers. The large diameter tubes are passed through rollers which travel in a spiral around the tube as shown in Figure 46, while the small tubes such as those used for condensers are straightened by passing through a series of rolls in two different planes as shown in Figure 47. Both of these straightening machines spring the tube in such a way as to tend to equalize any unbalanced mechanical strains that exist and thereby improve the service qualities of the tubing.

Testing

In order to control the quality of the product, samples are subjected to whatever tests are necessary to establish the properties of the tube required for the particular service they are to perform. In Figure 49 is shown an inspector marking samples to be delivered to the laboratories.

After straightening, the tubes are sawed to standard lengths and each one is subjected to an hydraulic pressure test. These various operations are shown in Figures 48 and 50.

In addition to pressure tests, each tube is examined by an expert and checked for dimensions and general quality before it is delivered to the shipping department for packing and shipment.

Cupping Process

The cupping process although used only to a small extent is preferred for certain kinds of tubing. In this process, the metal is pushed through a die by a round nosed punch. An operation of this kind is shown in Figure 45. In the liquid bath under the machine may be seen several tubes ready for the drawing operation. The operator at the right is holding a similar tube after the drawing operation. This tube is now ready for an annealing and pickling, after which it will be returned for the next draw and so on until the finished size is attained.

Special Sections

Although the bulk of the tubes are circular in section, other sections are also drawn. Figure 51 shows a number of special sections and serves simply to indicate the possibilities of the processes.

Figure 45. Drawing tubes by the cupping process. Two of the blanks from which the tubes are drawn may be seen in the liquid under the machine, and in front of the operator.

Figure 46. A tube passing through the spiral rolls of a straightening machine. The crooked tubes may be seen in the right background; while a portion of the straight tubes is visible in the right foreground. These straightening rolls operate on the machine in such a way, as to spring it and equalize mechanical strains, as well as to straighten it.

Figure 47. Straightening condenser tubes. These rolls spring the tube as well as straighten it, and therefore equalize mechanical strains left from the last drawing operation.

Figure 48. Cutting straightened condenser tubes to standard length.

Figure 49. Sampling condenser tubes for inspection tests. A certain percentage of all tubes manufactured are thus sampled for analyses and tests in the laboratory.

Figure 50. Hydraulic test of condenser tubes.

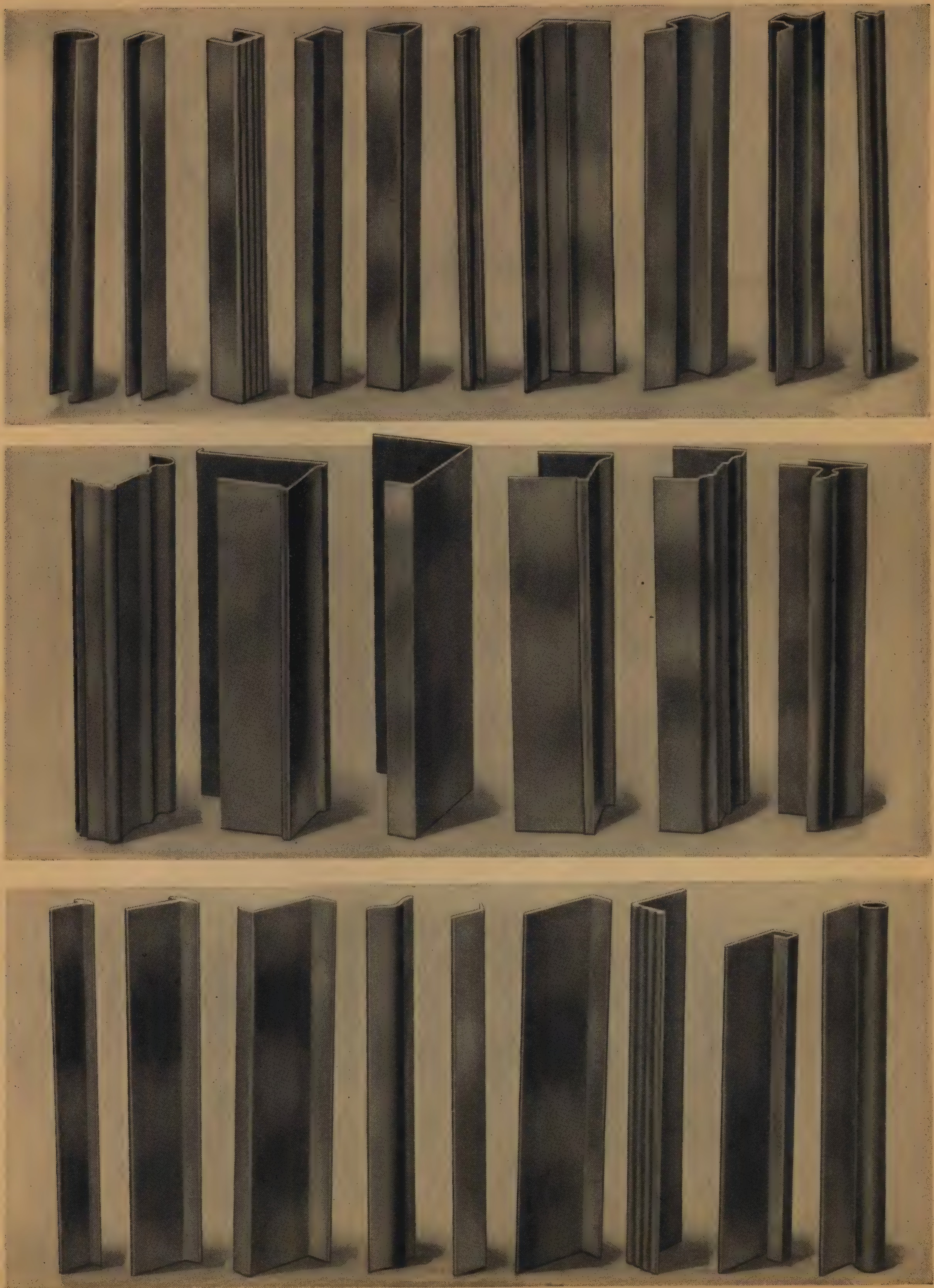
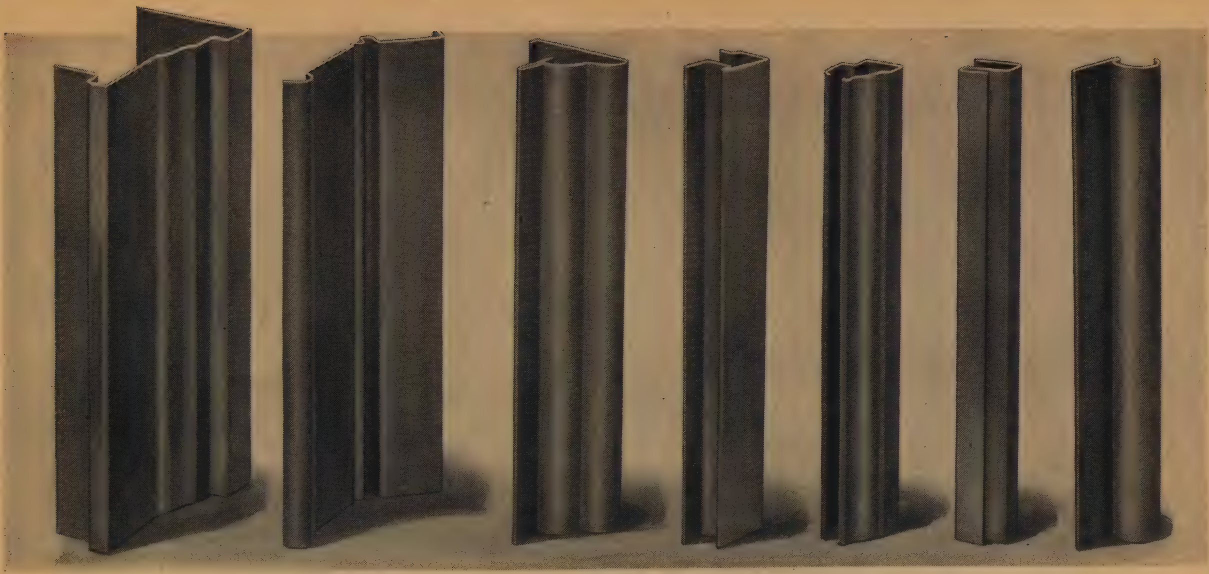
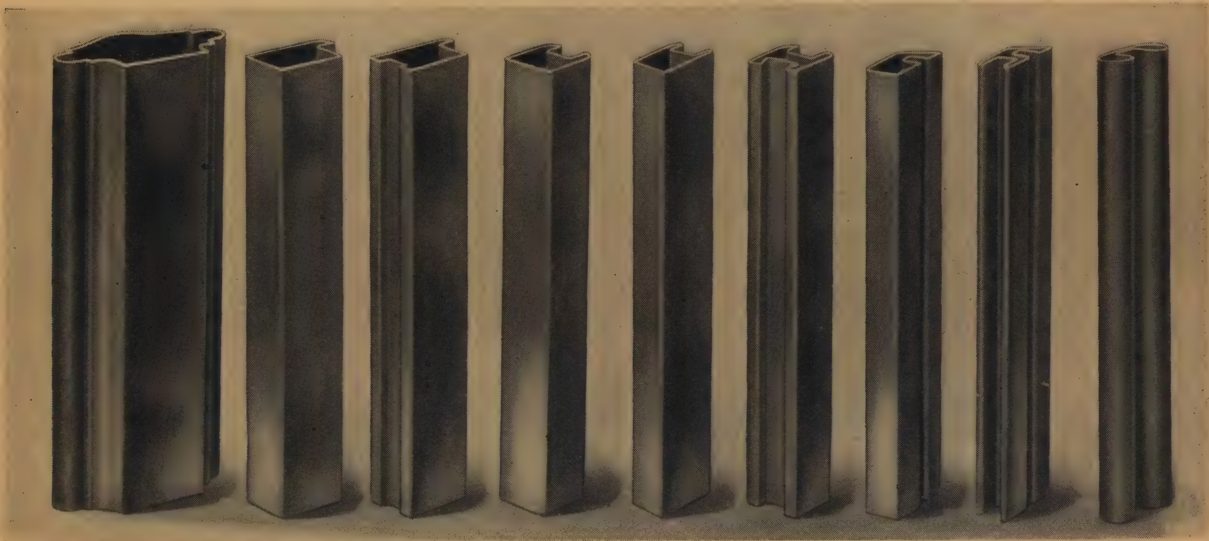
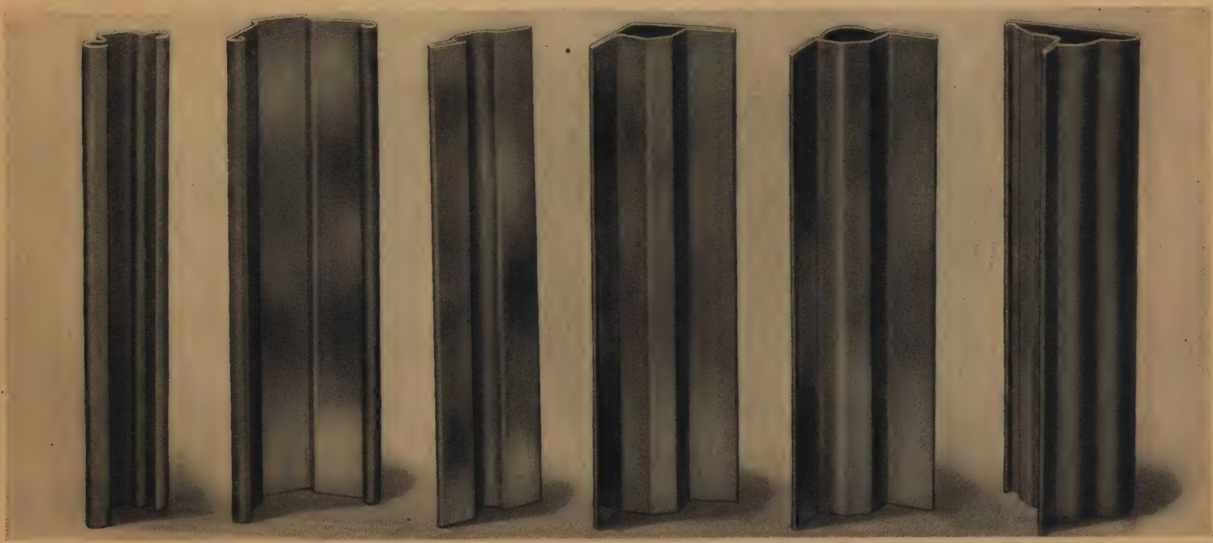


Figure 51. The Bridgeport Brass Company makes a specialty of drawing brass in all kinds of special shapes, of closed as well as opened sections. These sections find use in building construction wherever material having the properties of

either brass or copper is desirable. The principal applications are in connection with the construction of store fronts, skylights, fireproof metal trim, window sash, etc.

SHEET BRASS

Cutting off the Gate

IN the manufacture of sheet brass, bars are delivered from the electric casting shop to the rolling mills where the gate is cut off in an alligator shear as shown in Figure 52. An expert examines the piece cut off to determine whether the cut is deep enough to eliminate the pipe. He is also able to judge the quality of the casting by examining the metal disclosed by the cut.

Breaking Down and Straightening

Having trimmed the bars, they are inserted into a breaking-down roll after which they are straightened by passing through a series of rolls as shown in Figure 53. After being straightened, the surfaces of the casting are removed in a milling machine as shown in Figure 54. The bars are now ready for another pass through the breaking-down rolls as shown in Figure 55.

Annealing

Since mechanical working of brass or copper hardens the metal, it is necessary to anneal it at various stages in the rolling process. In Figure 56 is shown a group of annealing furnaces from one of which an annealed charge has just been withdrawn. These furnaces are so arranged that the hard brass is drawn in at one end by the same operation that the annealed brass is drawn out of the other. The temperature in these furnaces is accurately controlled by electric pyrometers, facilities being provided for reading the temperature at both ends and in the middle of the furnace. One of the indicating instruments is shown in Figure 57. A recorder is shown in Figure 61.

Some years ago the Bridgeport Brass Company originated the practice of using tandem rolls in the production of sheet brass, and protected the process by a series of patents. Figure 60 shows a set of these rolls in operation.

Rolling

Rolling brass is an art that up to the present time has never been successfully divorced from the human element of the operator. The process as a whole can be planned and controlled according to a definite program but the rollers themselves must be men who have had thorough training and long practical experience. The Bridgeport Brass Company has been in the business since 1865 and has produced rollers who are second to none in the country. Several of these men have been with the company for more than 30 years and one man has been with them for 47 years.

Sheet brass is marketed in various forms, depending upon the thickness of the metal and also upon the purpose for which it is to be used. It may be in straight flat bars, in wide coiled strips, or in narrow coiled strips.

Figure 52. Biting off the gate of a brass bar. The removed portion of every bar is examined by an expert to determine if the pipe has been entirely removed, and also to pass upon the quality of the metal.

Figure 53. Straightening bars after they have been passed through the breaking-down rolls preliminary to removing the exterior surface.

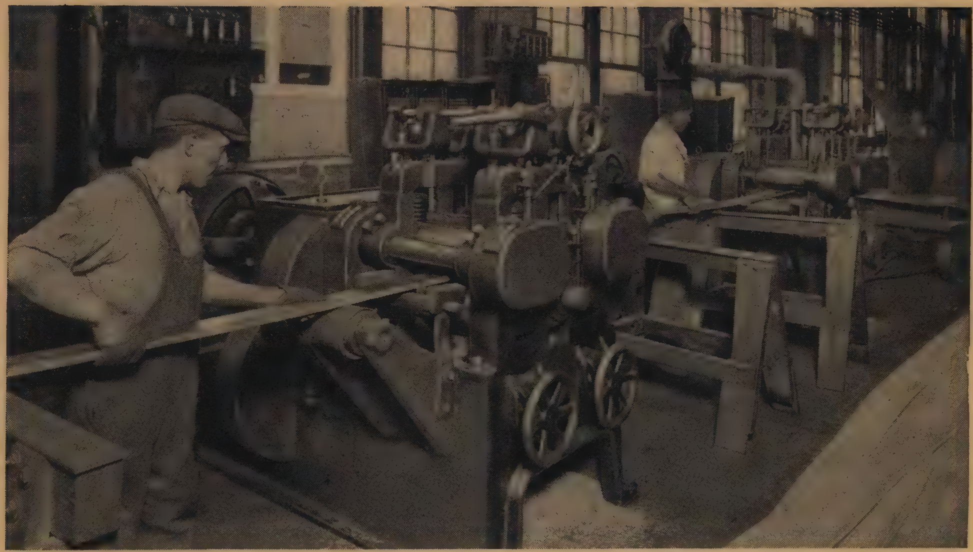


Figure 54. Milling the surface of straightened bars so as to remove mechanical flaws and surface impurities from the bar before rolling it to smaller sizes.

Figure 55. Milled bars passing through the breaking-down rolls.

Figure 56. Between the various stages of the rolling process, the bars are annealed so as to relieve rolling strains and soften the material. The charges are assembled on flat sheets of iron and coupled up in such a way that when a charge is withdrawn from the furnace, it drags in from the opposite end a fresh charge. The fresh charge may be easily identified by the glossy surfaces of the bars.

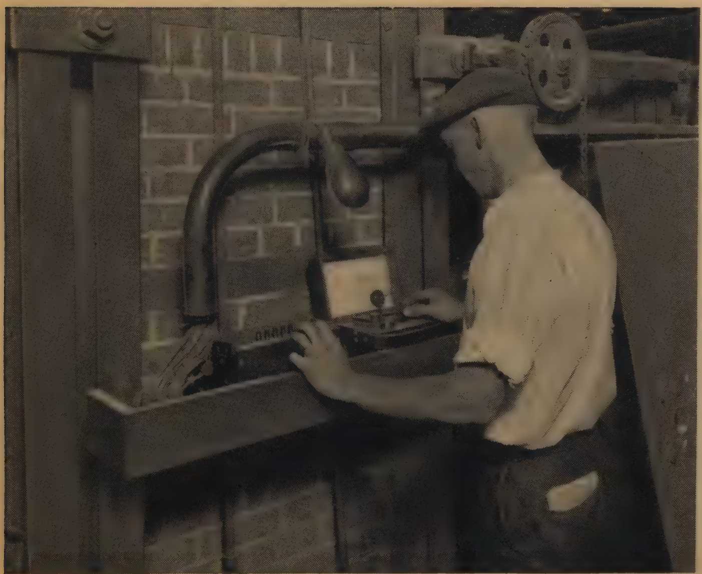


Figure 57. The temperature of the annealing furnaces is of the greatest importance, and therefore to facilitate its accurate control, recording and indicating pyrometers are provided. The operator here shown is reading the temperature of a group of furnaces, so as to check the adjustment of the heat. From the one point, he can read the temperature at the front, in the middle and at the rear of each furnace

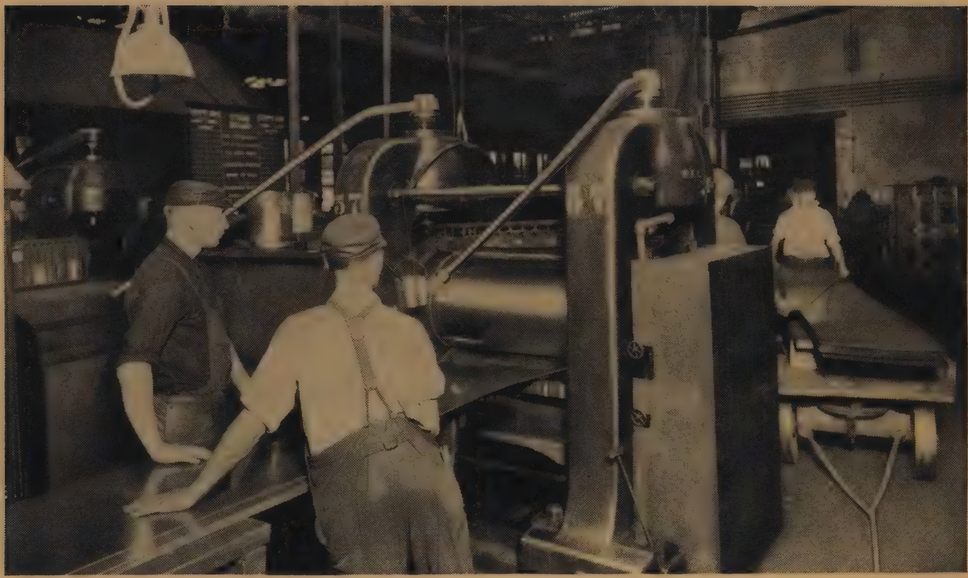


Figure 58. Rolling cold-rolled copper sheet

Figure 59. Rolling brass. The art of rolling brass is one that has not yet yielded to perfect scientific organization. The skill of the operator is still a factor of the greatest importance. The Bridgeport Brass Company is fortunate in having a large number of brass rollers that have been in its employ a great many years, and therefore are trained by experience to produce the results desired by the management. The roller shown in this picture has been in the employ of the company 47 years.

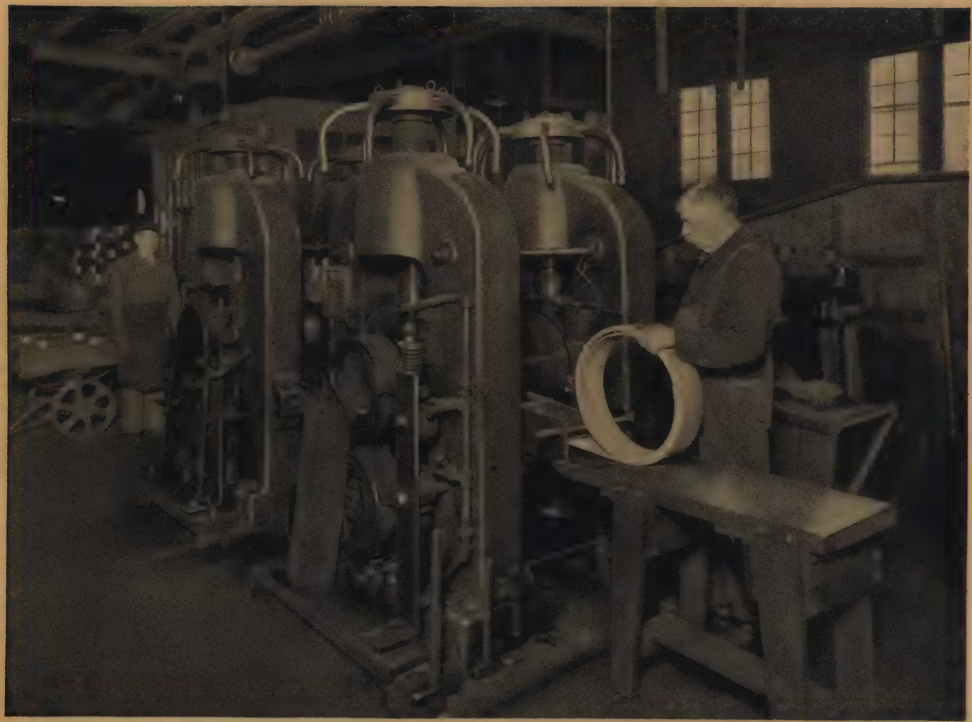


Figure 60. A set of tandem running-down rolls patented by the Bridgeport Brass Company and operated by a roller who has been in the employ of the company 38 years.

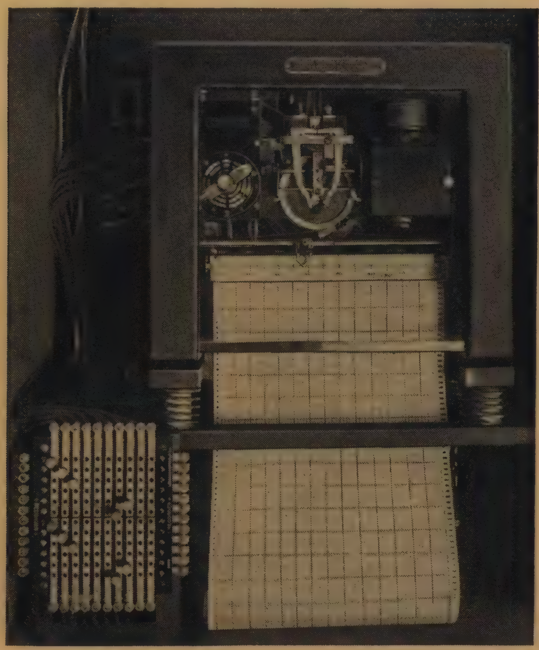


Figure 61. A recording pyrometer which automatically records the temperature of a group of annealing furnaces. By means of this instrument, an accurate record is kept of each batch of metal so that the control laboratory can always trace the history of samples taken for the purpose of controlling the mill operations.

RODS AND WIRES

THE Bridgeport Brass Company uses the extrusion process for the manufacture of brass rods, while bronze, copper, and Phono-Electric rods are made by the rolling process as described under "Phono-Electric Wire."

The brass billets from the electric casting shop are delivered to the saws, one of which is shown in Figure 62. From here they go to the heating furnace as shown in Figure 63 where they are brought to such temperature as will render the metal plastic.

Extrusion Process

The plastic billet is then inserted into the cylinder of the extrusion machine and pressure applied to one end of it by means of an hydraulically operated plunger. The metal being forced out through holes in a die at the other end of the cylinder emerges from the machine as rods. In Figure 64 the rods are seen coming from the machine and lying in the trough extending from its mouth. The muffle which feeds this machine is seen in the background at the right.

These rods are drawn to size and straightened for shipment, or wound on reels and delivered to the wire mills where they are drawn to size in the draw blocks.

Figure 62. Sawing off the gate of brass billets.

Figure 63. Brass billets on their way into the heating furnace of the extrusion machine.

Figure 64. The extrusion machine in operation. Billets in a plastic condition are taken from the heating furnace and inserted in a cylinder in the front end of the machine. The operator at the left then applies pressure against the end of the billet and forces it through a die, the rods issuing from the front of the machine as shown. The cylindrical cakes in the center foreground are the ends of the billets removed from the machine after the main portion has been extruded.

Figure 65. Drawing rods from the extrusion machine. This drawbench operates on the endless chain principle with reversing motors.

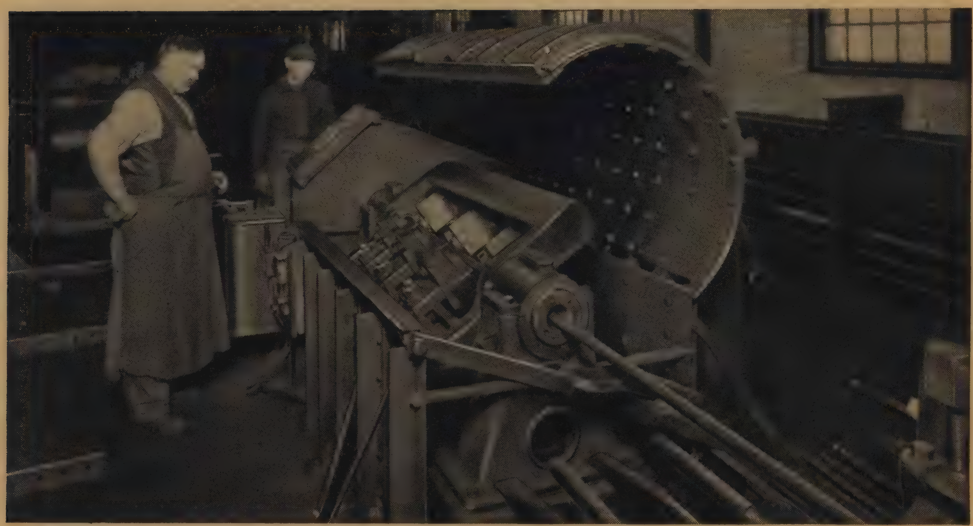


Figure 66. Straightening rods by passing them through three sets of spirally mounted rolls, which manipulate the rod in such a way as to relieve mechanical strains left by the drawing process. The cover of the machine is thrown up so as to show the method of mounting the rolls. In operation, the frame containing the roll sets rotates around the rod.

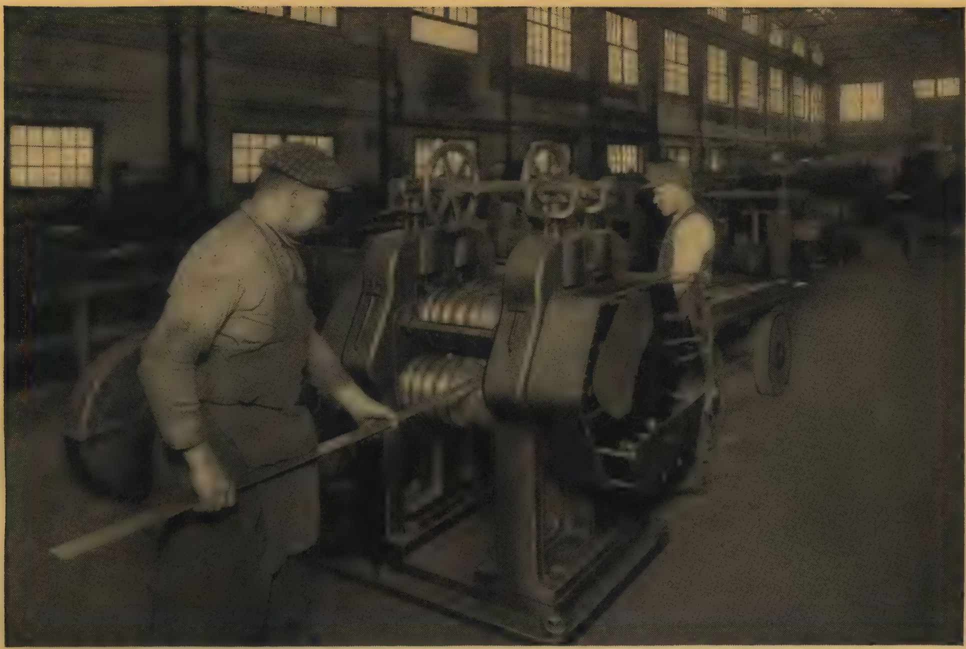


Figure 67. Springing machine for removing strains from bars and rods. The matter of mechanical strains in drawn bars is of the greatest importance, since their elimination largely determines the service characteristics of the material. This detail of tube and rod manufacture has been scientifically studied by the Bridgeport Brass Company, and the manufacturing technique so worked out as to eliminate practically all unbalanced strains. This result is obtained by properly choosing the various factors that enter into the annealing, pickling, lubricating, drawing and straightening processes, all of which have a bearing on the strains in the metal.

Figure 68. Straightening rod of small diameter.

LABORATORY AND RESEARCH DEPARTMENT

THE first step in placing the processes of the Bridgeport Brass Company on a scientific basis was the organization of a research laboratory. To begin with it was necessary to make a research man out of every foreman in the plant, many of whom were technically educated men, thoroughly trained in research methods. Having organized the force, the processes were carefully developed and scheduled, and then it was necessary to provide an inspection laboratory to insure the standards that had been set up. Therefore, the laboratory work of the department may be divided into two parts, the research work and the control routine work. The research work divides itself in two general classes, namely; research work on products of the company and research work on materials and equipment employed by the company in the manufacture of its products. The control laboratory systematically samples the product at the various stages of manufacture and performs chemical analyses and certain physical tests, depending upon the nature of the product and the particular step in the process from which the

Figure 69. Electrolytic cells for determining the copper and lead content of brasses and bronzes as applied in the control testing of the chemical laboratory. The glass beakers are closed at the top with semi-circular pieces of glass, as may be plainly seen at the left. The girl in the center is washing off these plates so as to prevent any possibility of error, due to part of the solution clinging to the cover plates. The girl in the background is setting up a cell. The cells are operated from a special low voltage motor-generator set.

sample was taken. In this way, it is possible to control closely the properties of the products passing through the plant.

The control laboratory is specially valuable in protecting the various alloys from any impurities there may be in the scrap used in their composition, and in this way serve as an accurate guide in the determination of the proportions of various kinds of scrap to be used in any given mixture.

The research department develops new alloys, studies details of the manufacturing processes with a view to eliminating wastes, and improving the quality of the product. It examines the fuel, lubricating oils and greases, the steel used for the dies and tools, and in many other ways develops and guards the manufacturing process in all its details.

The activities of this end of the business are far too numerous to be described in this publication, but some idea may be obtained of the extent and character of the equipment from the illustrations shown herewith.

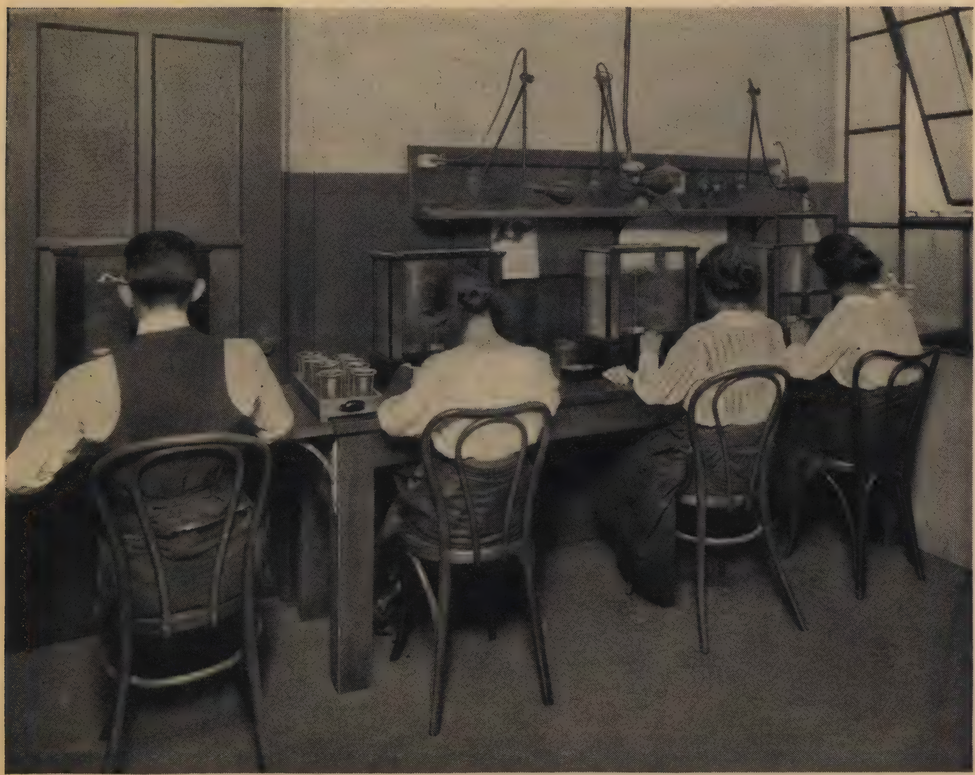


Figure 70. A view in the Balance Room where an important part of the control work is carried on.

Figure 71. In the control laboratory every possible precaution is taken to avoid errors. The measuring devices here shown are so constructed, that an accurate quantity of liquid is measured automatically. All the operator does is to pump until the measuring column is full to the top. An internal tube extending exactly to the upper graduation of the tube draws off the liquid automatically, leaving in the measuring tube the exact quantity required.

Figure 72. Special electric furnaces for burning out filter papers. This is another improvement calculated to eliminate possible errors. It supplants the old method of open flame burner with the ever present possibilities of loss, due to drafts or accidental upsetting

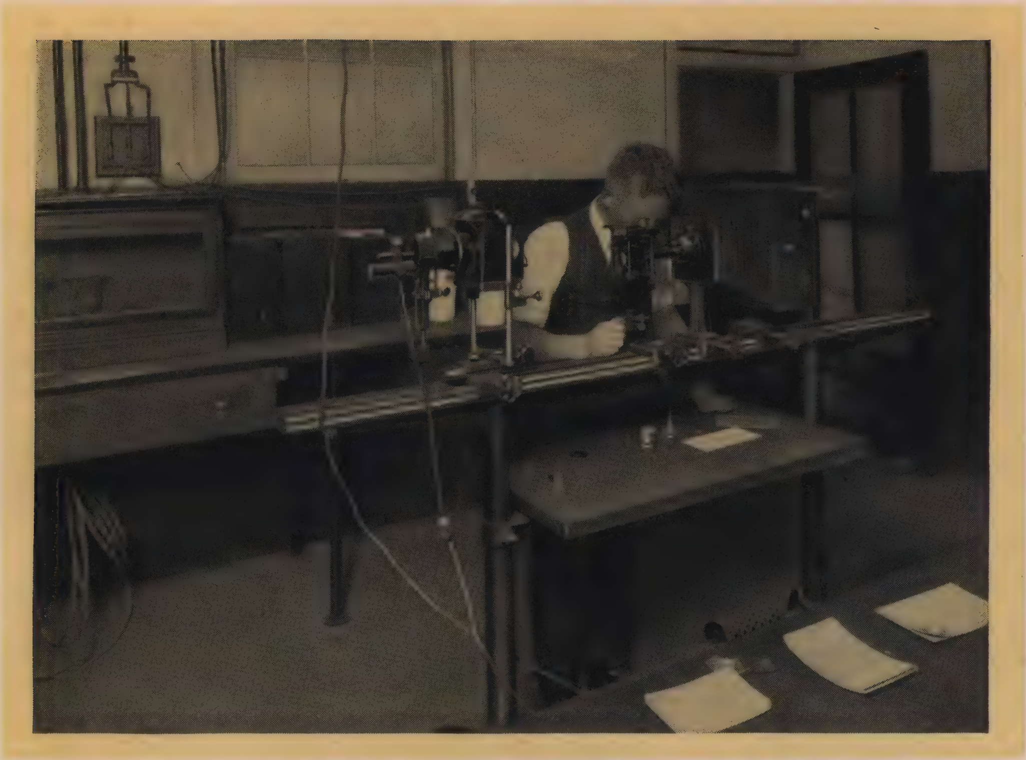


Figure 73. One of three micro-photographic machines. These machines are used both in control testing and investigation work. By means of systematic crystal count, the standard of Bridgeport Brass is maintained at every stage of the rolling and drawing processes.

Figure 74. A group of testing machines used in routine work for controlling the hardness and strength of tubes, rod and sheet metal.

Figure 75. Conductivity bridge for routine testing of Phono-Electric wire.

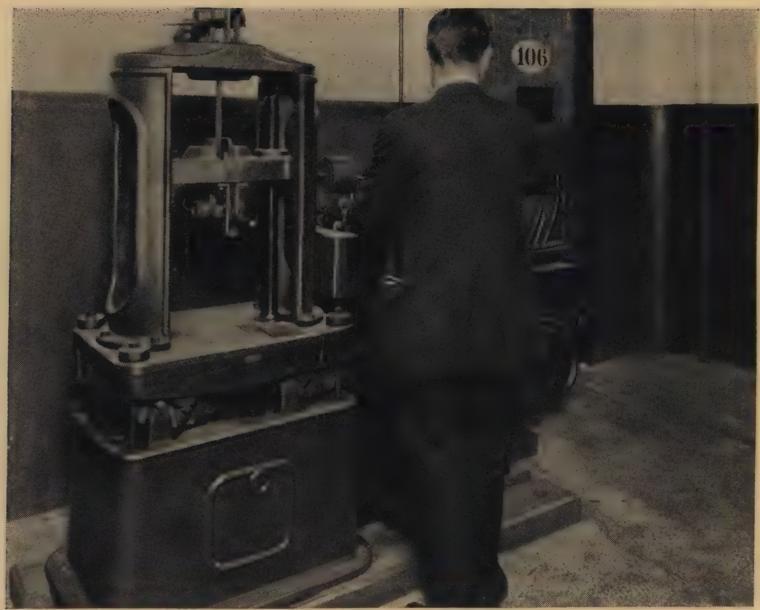


Figure 76. Machine for tensile and compression tests.

Figure 77. Miniature melting and annealing furnaces for brasses and bronzes. A bar mold and various tools required for casting are shown in the center of the picture. The research laboratory also uses a miniature electric furnace for investigation purposes.

Figure 78. One of the most important elements in the successful manufacture of rolled and drawn brass is the lubrication of the working parts. The Bridgeport Brass Company has found it necessary to compound its own oils and greases for these purposes. The equipment here shown, is part of the oil laboratory in which formulas for compounding are evolved.

Figure 79. Fuel testing equipment used for the inspection of fuels used in the power plant, and the various furnaces, which are purchased to specification and carefully checked.

Figure 80. Electrical apparatus for the determination of carbon content in steel. This apparatus is part of the equipment employed by the laboratory, which controls the metals used for the various dies and tools in the mills.

CHARACTERISTICS OF BRASS

THE useful alloys of copper and zinc cover a series from about 55 percent of copper and 45 percent of zinc up to pure copper, and exhibit a wide range of normal properties and characteristics according to the proportions of the two constituents present. Their physical characteristics when cold rolled and annealed vary with the proportion of the two ingredients as shown in Figure 81. These curves were produced by plotting the results of tests on samples of sheet of various mixtures which had been rolled to 0.1 inch thick and carefully annealed at about 650 degrees C.

Brass Mixtures

Mixtures high in zinc are relatively unimportant because of their comparative lack of toughness which prevents their being readily worked cold. When containing less than 63 percent of copper, however, they are readily rolled forged or extruded when hot. Within this range they are usually alloyed with other constituents for particular purposes. In the intermediate and lower ranges from 57 to 60 percent copper, iron and tin are added, either singly or in combination, to the extent of about 1 percent each, to increase strength, forming the manganese bronzes and naval brasses. The range from 60 to 63 percent combined with about 3 percent of lead covers the mixtures usually employed for making "leaded" or "free cutting" brass rod for screw machine use. From 63 to 70 percent are the high brasses ordinarily employed in making sheet and strip and which constitute by far the greater part of all the sheet produced. Mixtures containing the higher percentages of copper are necessarily more expensive and are required when color or certain qualities of toughness are important.

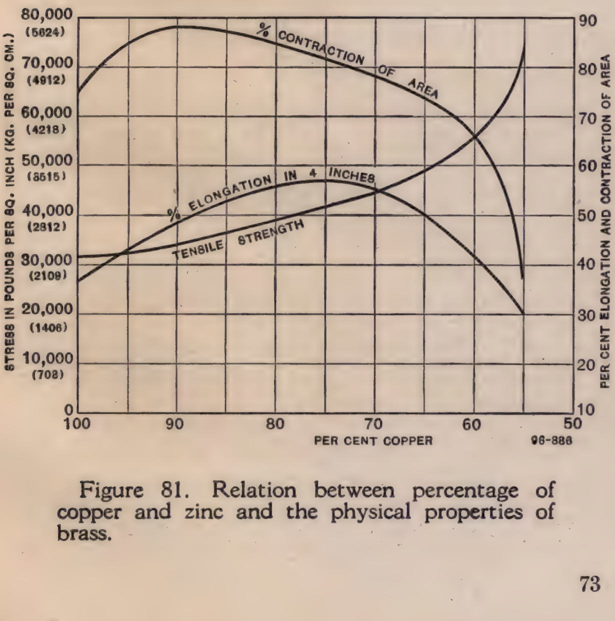


Figure 81. Relation between percentage of copper and zinc and the physical properties of brass.

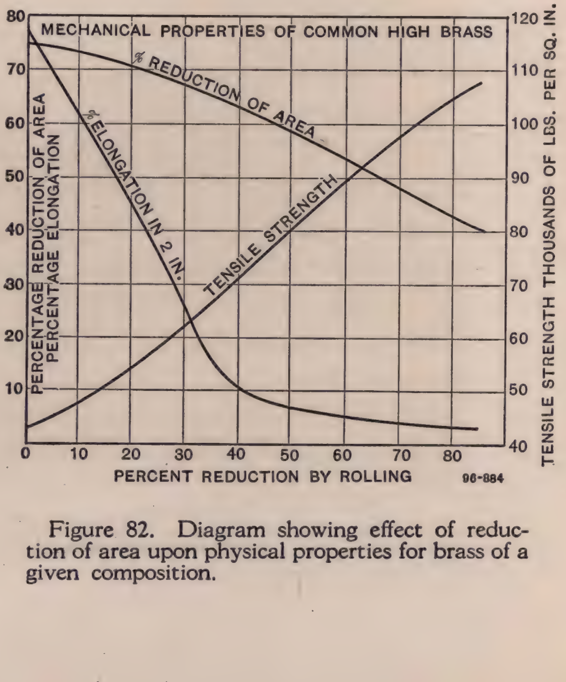


Figure 82. Diagram showing effect of reduction of area upon physical properties for brass of a given composition.

Effects of Cold Working

The properties of any individual mixture may be varied over a wide range by varying the amount of cold working from the annealed state and by varying the annealing temperatures from the cold worked state. The relative effect which a given amount of cold working or degree of annealing produces varies with the proportions of copper and zinc present.

The effect produced by a given amount of cold working is dependent solely upon the extent thereof irrespective of whether it is effected by a series of reductions or by one of the same total magnitude.

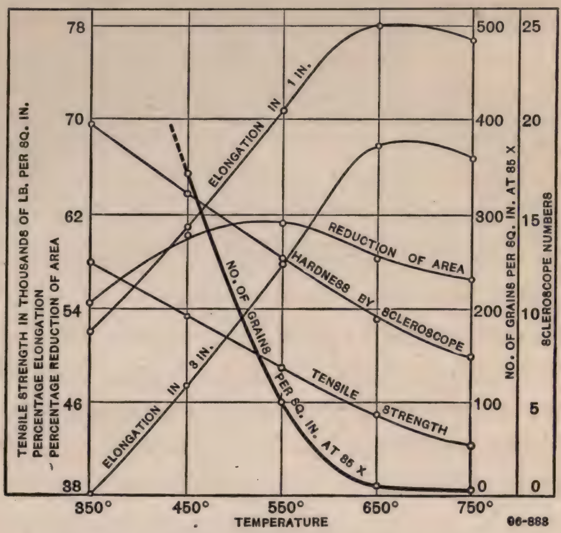


Figure 83. Diagram showing effect of annealing temperature upon physical properties for brass of a given composition.

Figure 82 shows the effect of cold rolling on brass containing 67 percent of copper. The percentage of reduction is the expression of the initial thickness minus the final thickness divided by the initial thickness and multiplied by 100.

Effects of Annealing

Figure 83 shows the effects of annealing a brass containing 67 percent of copper and 33 percent of zinc at varying temperatures. These values may be influenced somewhat by the degree of cold rolling to which the material has been subjected prior to annealing.

It is a usage of the trade to express the temper of cold rolled brass in terms designating the amount of reduction given in the final rolling after the last anneal. "1 number hard" or "quarter hard" corresponding to 10 percent, "2 numbers hard" or "half hard" to 20 percent and "4 numbers hard" or "hard" to 40 percent. Similarly the degree of annealing is somewhat roughly designated as light annealed, soft and dead soft, corresponding to about 500 deg. C., 600 deg. C., and 700 deg. C. respectively.

ADDITIONS AND IMPURITIES

THE quality of copper ordinarily employed in brass is exceedingly high, containing ordinarily 99.9 percent or more of copper, the balance being largely oxygen, the presence of which is required mainly to enable the metal to be cast in suitable form.

Zinc is, however, obtainable in various qualities, the chief variable impurity in which is lead, which is found in various percentages, from a few one hundredths up to as high as 2 percent.

Lead

The quality of brass is affected to a considerable degree by the amount of lead carried by the zinc of which it is produced. The effect of this ingredient is to lower its toughness, ductility and ability to withstand cold working processes, involving stretching and distortion. The presence of lead also has a very marked effect upon the ease with which brass can be cut with a tool, and where this property is of importance, lead is purposely added up to 3 percent or slightly over.

Iron

Next to lead the most important impurity carried by brass is iron, which is introduced partly with the zinc in which metal it exists in varying quantities according to the grade of the latter, and also from accidental contamination when in the molten state. The effect of iron is to reduce ductility and increase hardness and its influence in these respects is markedly detrimental when present in quantities over 0.1 percent.

Antimony and Bismuth

Other metallic impurities are seldom present in amounts sufficient to be detrimental, altho antimony and bismuth, which are particularly objectionable, are usually carried in minute amounts by copper.

Arsenic

Arsenic is sometimes present when grades of copper carrying that element are employed, but its effect, however, is ordinarily not pronounced and is useful rather than objectionable.

Tin

Tin is sometimes present by accident and sometimes by design. It increases the elastic limit and hardness of the material somewhat and acts as a deterrent to certain corrosive influences. Other elements are seldom found in the presence of good practice.

Accurate knowledge of the physical properties of brass and the use of scientific methods in its manufacture have not heretofore been of sufficiently wide employment to have resulted in any generally accepted practice in specifying the qualities of brass required for specific uses or in testing it for the determination of its suitability. As a general rule, therefore, the largest measure of satisfaction can be secured when the brass maker is cognizant of the exact purpose for which material is to be employed and in close cooperation with the user can apply his knowledge and skill to the selection of mixture and treatment best adapted for the purpose.

The chemical, physical and research laboratories of the Bridgeport Brass Company are in equipment and personnel second to none in their ability to determine and select the most suitable material for any particular usage.

Temper

It is equally important, however, that the temperature to which the material has been finally annealed, or the temper to which it has been rolled in case a temper is desired, be determined. The former may be ascertained by the ordinary tensile test, altho on thin material this is somewhat uncertain. It may also be determined by microscopic examination as the size of crystal varies, as shown by Figure 85, with varying temperatures of anneal.

Figure 84. Sample from extruded rod showing mixture of Alpha and Beta crystals.

The scleroscope and Brinnell tests are also useful in this connection, see Figure 74. The latter in particular is applicable to relatively thick sections. For thin sheet the Erichson machine is very useful. This instrument employs a dome shaped tool to draw sheet into the corresponding shape. This drawing action is continued until fracture occurs. The depth of the cup at fracture, which is measured by the machine, is a measure of the ductility of the material. At the same time the smoothness or roughness of the drawn cup indicates roughly the size of the crystal structure.

Specifications

Comprehensive attempts to draw specifications for various forms of wrought brass have not been conspicuously successful except in isolated instances. This is because of the absence of reliable data of a specific nature relating the various properties of brass to the requirements of individual users. As indicated by the data heretofore given an enormously wide range of physical characteristics can be imparted to brass by variations in composition, heat treatment and manipulation.

Figure 85. Microstructure of brass which has been annealed at various temperatures. Magnified 85 diameters.

Figure 86. Microstructure of brass which has received varying amounts of cold rolling. Magnified 85 diameters.

STRUCTURE

Crystals

THE crystallic structure of brass is revealed by the microscope. The crystals are of two kinds, known respectively as the alpha and beta crystals. The crystals shown in Figure 85 are alpha crystals, while Figure 84 shows a mixture of alpha and beta, the light ones being the former and the dark ones the latter.

Figure 85 shows the effect which varying annealing temperatures have on crystal size in the case of a sample of brass which has been rolled quite hard and then annealed at different temperatures.

Figure 86 shows the effect upon the crystal structure produced by cold rolling. In this instance a sample of very thoroughly annealed brass has been rolled to several degrees of hardness as stated.

Some of the useful mixtures are composed entirely of alpha crystals, some of beta crystals and others of a mixture of the two. These crystals separate out of the molten brass as solidification occurs and exist singly or together in any particular mixture according to its composition and temperature. The alpha crystals are relatively weak and ductile while the beta are stronger and less ductile.

Equilibrium Diagram

The equilibrium diagram, Figure 87, shows the relations existing between the proportions of copper and zinc, the temperature, and the crystallic structure. The line A.B.C. indicates the temperature at which, for various proportions of copper and spelter, solidification begins as a molten mass cools. The line A b_2 b_1 c_1 C shows the respective temperatures at which solidification is complete. It will be seen from this diagram that the presence of alpha or beta crystals is a function not alone of the proportions of copper and spelter present but of the temperature also. A brass containing 70 percent or over of copper will consist only of alpha crystals, whereas one containing 65 percent of copper will, when at a temperature of 700 deg. C. or over, contain some beta. If it is slowly cooled the beta will grow less as the temperature falls and finally disappear completely. If, however, it be rapidly cooled as by quenching in water there will be insufficient time for the latter transformation to take place and the presence of beta will be found upon microscopic examination. Similarly a brass containing 60 percent of copper will, after highly heating, contain all beta or a mixture of alpha and beta according as it is rapidly or slowly cooled.

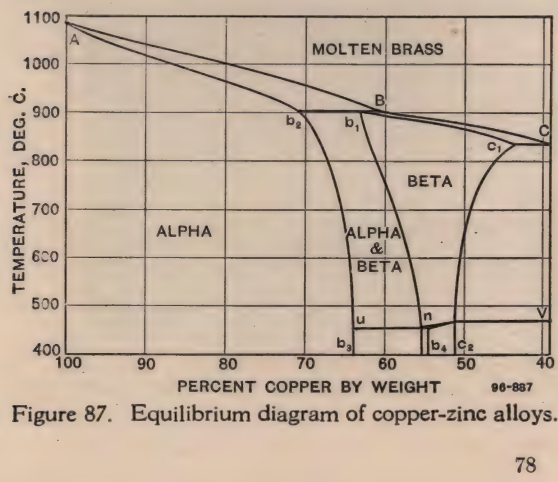


Figure 87. Equilibrium diagram of copper-zinc alloys.

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